B. Materials Reference

CHAPTER 24

THERMAL AND WATER VAPOR TRANSMISSION DATA

THIS chapter presents thermal and water vapor transmission data based on steady-state or equilibrium conditions. Chapter 3 covers heat transfer under transient or changing temperature conditions. Chapter 22 discusses selection of insulation materials and procedures for determining overall thermal resistances by simplified methods.

BUILDING ENVELOPES

Thermal Transmission Data for Building Components

The steady-state thermal resistances (R-values) of building components (walls, floors, windows, roof systems, etc.) can be calculated from the thermal properties of the materials in the component; or the heat flow through the assembled component can be measured directly with laboratory equipment such as the guarded hot box (ASTM *Standard* C 236) or the calibrated hot box (ASTM *Standard* C 976).

Tables 1 through 6 list thermal values, which may be used to calculate thermal resistances of building walls, floors, and ceilings. The values shown in these tables were developed under ideal conditions. In practice, overall thermal performance can be reduced significantly by such factors as improper installation and shrinkage, settling, or compression of the insulation (Tye and Desjarlais 1983; Tye 1985, 1986).

Most values in these tables were obtained by accepted ASTM test methods described in ASTM *Standards* C 177 and C 518 for materials and ASTM *Standards* C 236 and C 976 for building envelope components. Because commercially available materials vary, not all values apply to specific products.

The most accurate method of determining the overall thermal resistance for a combination of building materials assembled as a building envelope component is to test a representative sample by a hot box method. However, all combinations may not be conveniently or economically tested in this manner. For many simple constructions, calculated R-values agree reasonably well with values determined by hot box measurement.

The performance of materials fabricated in the field is especially subject to the quality of workmanship during construction and installation. Good workmanship becomes increasingly important as the insulation requirement becomes greater. Therefore, some engineers include additional insulation or other safety factors based on experience in their design.

Figure 1 shows how convection affects surface conductance of several materials. Other tests on smooth surfaces show that the average value of the convection part of the surface conductance decreases as the length of the surface increases.

Vapor retarders, which are discussed in Chapters 22 and 23, require special attention. Moisture from condensation or other sources may reduce the thermal resistance of insulation, but the effect of moisture must be determined for each material. For example, some materials with large air spaces are not affected significantly if the moisture content is less than 10% by weight, while the effect of moisture on other materials is approximately linear.

The preparation of this chapter is assigned to TC 4.4, Thermal Insulation and Moisture Retarders.

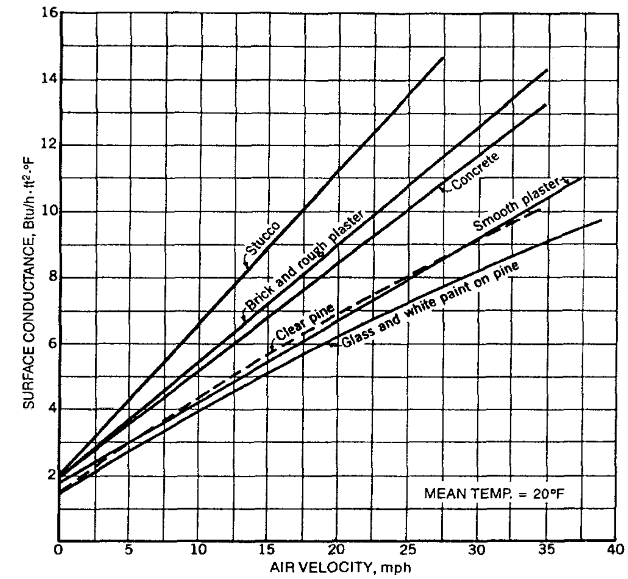


Fig. 1 Surface Conductance for Different Surfaces as Affected by Air Movement

Ideal conditions of components and installations are assumed in calculating overall R-values (i.e., insulating materials are of uniform nominal thickness and thermal resistance, air spaces are of uniform thickness and surface temperature, moisture effects are not involved, and installation details are in accordance with design). The National Institute of Standards and Technology Building Materials and Structures Report BMS 151 shows that measured values differ from calculated values for certain insulated constructions. For this reason, some engineers decrease the calculated R-values a moderate amount to account for departures of constructions from requirements and practices.

Tables 3 and 2 give values for well-sealed systems constructed with care. Field applications can differ substantially from laboratory test conditions. Air gaps in these insulation systems can seriously degrade thermal performance as a result of air movement due to both natural and forced convection. Sabine et al. (1975) found that the tabular values are not necessarily additive for multiple-layer, low-emittance air spaces, and tests on actual constructions should be conducted to accurately determine thermal resistance values.

Values for foil insulation products supplied by manufacturers must also be used with caution because they apply only to systems that are identical to the configuration in which the product was tested. In addition, surface oxidation, dust accumulation, condensation, and other factors that change the condition of the low-emittance surface can reduce the thermal effectiveness of

Table 1 Surface Conductances and Resistances for Air

Position of Surface	Direction of Heat Flow	Surface Emittance, ε: Non-reflective ε = 0.90 h_i	R	Reflective ε = 0.20 h_i	R	Reflective ε = 0.05 h_i	R
STILL AIR							
Horizontal	Upward	1.63	0.61	0.91	1.10	0.76	1.32
Sloping—45°	Upward	1.60	0.62	0.88	1.14	0.73	1.37
Vertical	Horizontal	1.46	0.68	0.74	1.35	0.59	1.70
Sloping—45°	Downward	1.32	0.76	0.60	1.67	0.45	2.22
Horizontal	Downward	1.08	0.92	0.37	2.70	0.22	4.55
MOVING AIR (Any position)		h_o	R				
15-mph Wind (for winter)	Any	6.00	0.17	—	—	—	—
7.5-mph Wind (for summer)	Any	4.00	0.25	—	—	—	—

Notes:
1. Surface conductance h_i and h_o measured in Btu/h·ft²·°F; resistance R in °F·ft²·h/Btu.
2. No surface has both an air space resistance value and a surface resistance value.
3. For ventilated attics or spaces above ceilings under summer conditions (heat flow down), see Table 5.
4. Conductances are for surfaces of the stated emittance facing virtual blackbody surroundings at the same temperature as the ambient air. Values are based on a surface-air temperature difference of 10°F and for surface temperatures of 70°F.
5. See Chapter 3 for more detailed information, especially Tables 5 and 6, and see Figure 1 for additional data.
6. Condensate can have a significant impact on surface emittance (see Table 2).

Table 2 Emittance Values of Various Surfaces and Effective Emittances of Air Spaces[a]

Surface	Average Emittance ε	Effective Emittance ε_{eff} of Air Space: One Surface Emittance ε; Other, 0.9	Both Surfaces Emittance ε
Aluminum foil, bright	0.05	0.05	0.03
Aluminum foil, with condensate just visible (> 0.7 gr/ft²)	0.30[b]	0.29	—
Aluminum foil, with condensate clearly visible (> 2.9 gr/ft²)	0.70[b]	0.65	—
Aluminum sheet	0.12	0.12	0.06
Aluminum coated paper, polished	0.20	0.20	0.11
Steel, galvanized, bright	0.25	0.24	0.15
Aluminum paint	0.50	0.47	0.35
Building materials: wood, paper, masonry, nonmetallic paints	0.90	0.82	0.82
Regular glass	0.84	0.77	0.72

[a]These values apply in the 4 to 40 μm range of the electromagnetic spectrum.
[b]Values are based on data presented by Bassett and Trethowen (1984).

these insulation systems (Hooper and Moroz 1952). Deterioration results from contact with several types of solutions, either acidic or basic (e.g., wet cement mortar or the preservatives found in decay-resistant lumber). Polluted environments may cause rapid and severe material degradation. However, site inspections show a predominance of well-preserved installations and only a small number of cases in which rapid and severe deterioration has occurred. An extensive review of the reflective building insulation system performance literature is provided by Goss and Miller (1989).

CALCULATING OVERALL THERMAL RESISTANCES

Relatively small, highly conductive elements in an insulating layer called thermal bridges can substantially reduce the average thermal resistance of a component. Examples include wood and metal studs in frame walls, concrete webs in concrete masonry walls, and metal ties or other elements in insulated wall panels. The following examples illustrate the calculation of R-values and U-factors for components containing thermal bridges.

These conditions are assumed in calculating the design R-values:

- Equilibrium or steady-state heat transfer, disregarding effects of thermal storage
- Surrounding surfaces at ambient air temperature
- Exterior wind velocity of 15 mph for winter (surface with R = 0.17°F·ft²·h/Btu) and 7.5 mph for summer (surface with R = 0.25°F·ft²·h/Btu)
- Surface emittance of ordinary building materials is 0.90

Wood Frame Walls

The average overall R-values and U-factors of wood frame walls can be calculated by assuming either parallel heat flow paths through areas with different thermal resistances or by assuming isothermal planes. Equations (1) through (5) from Chapter 22 are used.

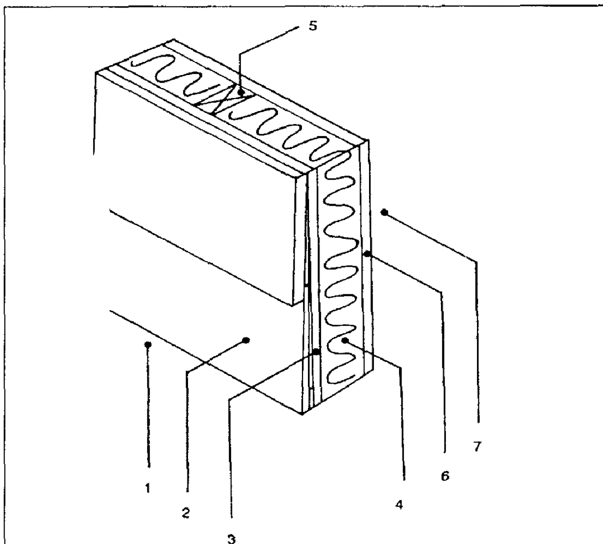


Fig. 2 Insulated Wood Frame Wall (Example 1)

The framing factor or fraction of the building component that is framing depends on the specific type of construction, and it may vary based on local construction practices—even for the same type of construction. For stud walls 16 in. on center (OC), the fraction of insulated cavity may be as low as 0.75, where the fraction of studs, plates, and sills is 0.21 and the fraction of headers is 0.04. For studs 24 in. OC, the respective values are 0.78, 0.18, and 0.04. These fractions contain an allowance for multiple studs, plates, sills, extra framing around windows, headers, and band joists. These assumed framing fractions are used in the following example, to illustrate the importance of including the effect of framing in determining the overall thermal conductance of a building. The actual framing fraction should be calculated for each specific construction.

Table 3 Thermal Resistances of Plane Air Spaces[a,b,c], °F·ft²·h/Btu

		Air Space		0.5-in. Air Space[c]					0.75-in. Air Space[c]				
				Effective Emittance ε_{eff}[d,e]					Effective Emittance ε_{eff}[d,e]				
Position of Air Space	**Direction of Heat Flow**	**Mean Temp.[d], °F**	**Temp. Diff.[d], °F**	**0.03**	**0.05**	**0.2**	**0.5**	**0.82**	**0.03**	**0.05**	**0.2**	**0.5**	**0.82**
		90	10	2.13	2.03	1.51	0.99	0.73	2.34	2.22	1.61	1.04	0.75
		50	30	1.62	1.57	1.29	0.96	0.75	1.71	1.66	1.35	0.99	0.77
		50	10	2.13	2.05	1.60	1.11	0.84	2.30	2.21	1.70	1.16	0.87
Horiz.	Up	0	20	1.73	1.70	1.45	1.12	0.91	1.83	1.79	1.52	1.16	0.93
		0	10	2.10	2.04	1.70	1.27	1.00	2.23	2.16	1.78	1.31	1.02
		−50	20	1.69	1.66	1.49	1.23	1.04	1.77	1.74	1.55	1.27	1.07
		−50	10	2.04	2.00	1.75	1.40	1.16	2.16	2.11	1.84	1.46	1.20
		90	10	2.44	2.31	1.65	1.06	0.76	2.96	2.78	1.88	1.15	0.81
		50	30	2.06	1.98	1.56	1.10	0.83	1.99	1.92	1.52	1.08	0.82
45°		50	10	2.55	2.44	1.83	1.22	0.90	2.90	2.75	2.00	1.29	0.94
Slope	Up	0	20	2.20	2.14	1.76	1.30	1.02	2.13	2.07	1.72	1.28	1.00
		0	10	2.63	2.54	2.03	1.44	1.10	2.72	2.62	2.08	1.47	1.12
		−50	20	2.08	2.04	1.78	1.42	1.17	2.05	2.01	1.76	1.41	1.16
		−50	10	2.62	2.56	2.17	1.66	1.33	2.53	2.47	2.10	1.62	1.30
		90	10	2.47	2.34	1.67	1.06	0.77	3.50	3.24	2.08	1.22	0.84
		50	30	2.57	2.46	1.84	1.23	0.90	2.91	2.77	2.01	1.30	0.94
		50	10	2.66	2.54	1.88	1.24	0.91	3.70	3.46	2.35	1.43	1.01
Vertical	Horiz.	0	20	2.82	2.72	2.14	1.50	1.13	3.14	3.02	2.32	1.58	1.18
		0	10	2.93	2.82	2.20	1.53	1.15	3.77	3.59	2.64	1.73	1.26
		−50	20	2.90	2.82	2.35	1.76	1.39	2.90	2.83	2.36	1.77	1.39
		−50	10	3.20	3.10	2.54	1.87	1.46	3.72	3.60	2.87	2.04	1.56
		90	10	2.48	2.34	1.67	1.06	0.77	3.53	3.27	2.10	1.22	0.84
		50	30	2.64	2.52	1.87	1.24	0.91	3.43	3.23	2.24	1.39	0.99
45°		50	10	2.67	2.55	1.89	1.25	0.92	3.81	3.57	2.40	1.45	1.02
Slope	Down	0	20	2.91	2.80	2.19	1.52	1.15	3.75	3.57	2.63	1.72	1.26
		0	10	2.94	2.83	2.21	1.53	1.15	4.12	3.91	2.81	1.80	1.30
		−50	20	3.16	3.07	2.52	1.86	1.45	3.78	3.65	2.90	2.05	1.57
		−50	10	3.26	3.16	2.58	1.89	1.47	4.35	4.18	3.22	2.21	1.66
		90	10	2.48	2.34	1.67	1.06	0.77	3.55	3.29	2.10	1.22	0.85
		50	30	2.66	2.54	1.88	1.24	0.91	3.77	3.52	2.38	1.44	1.02
		50	10	2.67	2.55	1.89	1.25	0.92	3.84	3.59	2.41	1.45	1.02
Horiz.	Down	0	20	2.94	2.83	2.20	1.53	1.15	4.18	3.96	2.83	1.81	1.30
		0	10	2.96	2.85	2.22	1.53	1.16	4.25	4.02	2.87	1.82	1.31
		−50	20	3.25	3.15	2.58	1.89	1.47	4.60	4.41	3.36	2.28	1.69
		−50	10	3.28	3.18	2.60	1.90	1.47	4.71	4.51	3.42	2.30	1.71
		Air Space		**1.5-in. Air Space[c]**					**3.5-in. Air Space[c]**				
		90	10	2.55	2.41	1.71	1.08	0.77	2.84	2.66	1.83	1.13	0.80
		50	30	1.87	1.81	1.45	1.04	0.80	2.09	2.01	1.58	1.10	0.84
		50	10	2.50	2.40	1.81	1.21	0.89	2.80	2.66	1.95	1.28	0.93
Horiz.	Up	0	20	2.01	1.95	1.63	1.23	0.97	2.25	2.18	1.79	1.32	1.03
		0	10	2.43	2.35	1.90	1.38	1.06	2.71	2.62	2.07	1.47	1.12
		−50	20	1.94	1.91	1.68	1.36	1.13	2.19	2.14	1.86	1.47	1.20
		−50	10	2.37	2.31	1.99	1.55	1.26	2.65	2.58	2.18	1.67	1.33
		90	10	2.92	2.73	1.86	1.14	0.80	3.18	2.96	1.97	1.18	0.82
		50	30	2.14	2.06	1.61	1.12	0.84	2.26	2.17	1.67	1.15	0.86
45°		50	10	2.88	2.74	1.99	1.29	0.94	3.12	2.95	2.10	1.34	0.96
Slope	Up	0	20	2.30	2.23	1.82	1.34	1.04	2.42	2.35	1.90	1.38	1.06
		0	10	2.79	2.69	2.12	1.49	1.13	2.98	2.87	2.23	1.54	1.16
		−50	20	2.22	2.17	1.88	1.49	1.21	2.34	2.29	1.97	1.54	1.25
		−50	10	2.71	2.64	2.23	1.69	1.35	2.87	2.79	2.33	1.75	1.39
		90	10	3.99	3.66	2.25	1.27	0.87	3.69	3.40	2.15	1.24	0.85
		50	30	2.58	2.46	1.84	1.23	0.90	2.67	2.55	1.89	1.25	0.91
		50	10	3.79	3.55	2.39	1.45	1.02	3.63	3.40	2.32	1.42	1.01
Vertical	Horiz.	0	20	2.76	2.66	2.10	1.48	1.12	2.88	2.78	2.17	1.51	1.14
		0	10	3.51	3.35	2.51	1.67	1.23	3.49	3.33	2.50	1.67	1.23
		−50	20	2.64	2.58	2.18	1.66	1.33	2.82	2.75	2.30	1.73	1.37
		−50	10	3.31	3.21	2.62	1.91	1.48	3.40	3.30	2.67	1.94	1.50
		90	10	5.07	4.55	2.56	1.36	0.91	4.81	4.33	2.49	1.34	0.90
		50	30	3.58	3.36	2.31	1.42	1.00	3.51	3.30	2.28	1.40	1.00
45°		50	10	5.10	4.66	2.85	1.60	1.09	4.74	4.36	2.73	1.57	1.08
Slope	Down	0	20	3.85	3.66	2.68	1.74	1.27	3.81	3.63	2.66	1.74	1.27
		0	10	4.92	4.62	3.16	1.94	1.37	4.59	4.32	3.02	1.88	1.34
		−50	20	3.62	3.50	2.80	2.01	1.54	3.77	3.64	2.90	2.05	1.57
		−50	10	4.67	4.47	3.40	2.29	1.70	4.50	4.32	3.31	2.25	1.68
		90	10	6.09	5.35	2.79	1.43	0.94	10.07	8.19	3.41	1.57	1.00
		50	30	6.27	5.63	3.18	1.70	1.14	9.60	8.17	3.86	1.88	1.22
		50	10	6.61	5.90	3.27	1.73	1.15	11.15	9.27	4.09	1.93	1.24
Horiz.	Down	0	20	7.03	6.43	3.91	2.19	1.49	10.90	9.52	4.87	2.47	1.62
		0	10	7.31	6.66	4.00	2.22	1.51	11.97	10.32	5.08	2.52	1.64
		−50	20	7.73	7.20	4.77	2.85	1.99	11.64	10.49	6.02	3.25	2.18
		−50	10	8.09	7.52	4.91	2.89	2.01	12.98	11.56	6.36	3.34	2.22

[a]See Chapter 22, section Factors Affecting Heat Transfer across Air Spaces. Thermal resistance values were determined from the relation, $R = 1/C$, where $C = h_c + \varepsilon_{eff} h_r$, h_c is the conduction-convection coefficient, $\varepsilon_{eff} h_r$ is the radiation coefficient ≈ $0.0068\varepsilon_{eff}[(t_m + 460)/100]^3$, and t_m is the mean temperature of the air space. Values for h_c were determined from data developed by Robinson et al. (1954). Equations (5) through (7) in Yarbrough (1983) show the data in this table in analytic form. For extrapolation from this table to air spaces less than 0.5 in. (as in insulating window glass), assume $h_c = 0.159(1 + 0.0016\, t_m)/l$ where l is the air space thickness in inches, and h_c is heat transfer through the air space only.

[b]Values are based on data presented by Robinson et al. (1954). (Also see Chapter 3, Tables 3 and 4, and Chapter 36). Values apply for ideal conditions, i.e., air spaces of uniform thickness bounded by plane, smooth, parallel surfaces with no air leakage to or from the space. When accurate values are required, use overall U-factors determined through calibrated hot box (ASTM C 976) or guarded hot box (ASTM C 236) testing. Thermal resistance values for multiple air spaces must be based on careful estimates of mean temperature differences for each air space.

[c]A single resistance value cannot account for multiple air spaces; each air space requires a separate resistance calculation that applies only for the established boundary conditions. Resistances of horizontal spaces with heat flow downward are substantially independent of temperature difference.

[d]Interpolation is permissible for other values of mean temperature, temperature difference, and effective emittance ε_{eff}. Interpolation and moderate extrapolation for air spaces greater than 3.5 in. are also permissible.

[e]Effective emittance ε_{eff} of the air space is given by $1/\varepsilon_{eff} = 1/\varepsilon_1 + 1/\varepsilon_2 - 1$, where ε_1 and ε_2 are the emittances of the surfaces of the air space (see Table 2).

Table 4 Typical Thermal Properties of Common Building and Insulating Materials—Design Values[a]

Description	Density, lb/ft³	Conductivity[b] (k), $\frac{\text{Btu·in}}{\text{h·ft}^2\text{·°F}}$	Conductance (C), $\frac{\text{Btu}}{\text{h·ft}^2\text{·°F}}$	Resistance[c] (R): Per Inch Thickness ($1/k$), $\frac{\text{°F·ft}^2\text{·h}}{\text{Btu·in}}$	Resistance[c] (R): For Thickness Listed ($1/C$), $\frac{\text{°F·ft}^2\text{·h}}{\text{Btu}}$	Specific Heat, $\frac{\text{Btu}}{\text{lb·°F}}$
BUILDING BOARD						
Asbestos-cement board	120	4.0	—	0.25	—	0.24
Asbestos-cement board ... 0.125 in.	120	—	33.00	—	0.03	
Asbestos-cement board ... 0.25 in.	120	—	16.50	—	0.06	
Gypsum or plaster board ... 0.375 in.	50	—	3.10	—	0.32	0.26
Gypsum or plaster board ... 0.5 in.	50	—	2.22	—	0.45	
Gypsum or plaster board ... 0.625 in.	50	—	1.78	—	0.56	
Plywood (Douglas Fir)[d]	34	0.80	—	1.25	—	0.29
Plywood (Douglas Fir) ... 0.25 in.	34	—	3.20	—	0.31	
Plywood (Douglas Fir) ... 0.375 in.	34	—	2.13	—	0.47	
Plywood (Douglas Fir) ... 0.5 in.	34	—	1.60	—	0.62	
Plywood (Douglas Fir) ... 0.625 in.	34	—	1.29	—	0.77	
Plywood or wood panels ... 0.75 in.	34	—	1.07	—	0.93	0.29
Vegetable fiber board						
Sheathing, regular density[e] ... 0.5 in.	18	—	0.76	—	1.32	0.31
... 0.78125 in.	18	—	0.49	—	2.06	
Sheathing intermediate density[e] ... 0.5 in.	22	—	0.92	—	1.09	0.31
Nail-base sheathing[e] ... 0.5 in.	25	—	0.94	—	1.06	0.31
Shingle backer ... 0.375 in.	18	—	1.06	—	0.94	0.31
Shingle backer ... 0.3125 in.	18	—	1.28	—	0.78	
Sound deadening board ... 0.5 in.	15	—	0.74	—	1.35	0.30
Tile and lay-in panels, plain or acoustic	18	0.40	—	2.50	—	0.14
... 0.5 in.	18	—	0.80	—	1.25	
... 0.75 in.	18	—	0.53	—	1.89	
Laminated paperboard	30	0.50	—	2.00	—	0.33
Homogeneous board from repulped paper	30	0.50	—	2.00	—	0.28
Hardboard[e]						
Medium density	50	0.73	—	1.37	—	0.31
High density, service-tempered grade and service grade	55	0.82	—	1.22	—	0.32
High density, standard-tempered grade	63	1.00	—	1.00	—	0.32
Particleboard[e]						
Low density	37	0.71	—	1.41	—	0.31
Medium density	50	0.94	—	1.06	—	0.31
High density	62	.5	1.18	—	0.85	—
Underlayment ... 0.625 in.	40	—	1.22	—	0.82	0.29
Waferboard	37	0.63	—	1.59	—	—
Wood subfloor ... 0.75 in.	—	—	1.06	—	0.94	0.33
BUILDING MEMBRANE						
Vapor—permeable felt	—	—	16.70	—	0.06	
Vapor—seal, 2 layers of mopped 15-lb felt	—	—	8.35	—	0.12	
Vapor—seal, plastic film	—	—	—	—	Negl.	
FINISH FLOORING MATERIALS						
Carpet and fibrous pad	—	—	0.48	—	2.08	0.34
Carpet and rubber pad	—	—	0.81	—	1.23	0.33
Cork tile ... 0.125 in.	—	—	3.60	—	0.28	0.48
Terrazzo ... 1 in.	—	—	12.50	—	0.08	0.19
Tile—asphalt, linoleum, vinyl, rubber	—	—	20.00	—	0.05	0.30
vinyl asbestos						0.24
ceramic						0.19
Wood, hardwood finish ... 0.75 in.	—	—	1.47	—	0.68	
INSULATING MATERIALS						
Blanket and Batt[f,g]						
Mineral fiber, fibrous form processed from rock, slag, or glass						
approx. 3-4 in.	0.4-2.0	—	0.091	—	11	
approx. 3.5 in.	0.4-2.0	—	0.077	—	13	
approx. 3.5 in.	1.2-1.6	—	0.067	—	15	
approx. 5.5-6.5 in.	0.4-2.0	—	0.053	—	19	
approx. 5.5 in.	0.6-1.0	—	0.048	—	21	
approx. 6-7.5 in.	0.4-2.0	—	0.045	—	22	
approx. 8.25-10 in.	0.4-2.0	—	0.033	—	30	
approx. 10-13 in.	0.4-2.0	—	0.026	—	38	
Board and Slabs						
Cellular glass	8.0	0.33	—	3.03	—	0.18
Glass fiber, organic bonded	4.0-9.0	0.25	—	4.00	—	0.23
Expanded perlite, organic bonded	1.0	0.36	—	2.78	—	0.30
Expanded rubber (rigid)	4.5	0.22	—	4.55	—	0.40
Expanded polystyrene, extruded (smooth skin surface) (CFC-12 exp.)	1.8-3.5	0.20	—	5.00	—	0.29

Table 4 Typical Thermal Properties of Common Building and Insulating Materials—Design Values[a] (Continued)

Description	Density, lb/ft³	Conductivity[b] (k), Btu·in/h·ft²·°F	Conductance (C), Btu/h·ft²·°F	Resistance[c] (R): Per Inch Thickness (1/k), °F·ft²·h/Btu·in	Resistance[c] (R): For Thickness Listed (1/C), °F·ft²·h/Btu	Specific Heat, Btu/lb·°F
Expanded polystyrene, extruded (smooth skin surface) (HCFC-142b exp.)[h]	1.8-3.5	0.20	—	5.00	—	0.29
Expanded polystyrene, molded beads	1.0	0.26	—	3.85	—	—
	1.25	0.25	—	4.00	—	—
	1.5	0.24	—	4.17	—	—
	1.75	0.24	—	4.17	—	—
	2.0	0.23	—	4.35	—	—
Cellular polyurethane/polyisocyanurate[i] (CFC-11 exp.) (unfaced)	1.5	0.16-0.18	—	6.25-5.56	—	0.38
Cellular polyisocyanurate[i] (CFC-11 exp.) (gas-permeable facers)	1.5-2.5	0.16-0.18	—	6.25-5.56	—	0.22
Cellular polyisocyanurate[j] (CFC-11 exp.) (gas-impermeable facers)	2.0	0.14	—	7.04	—	0.22
Cellular phenolic (closed cell) (CFC-11, CFC-113 exp.)[k]	3.0	0.12	—	8.20	—	—
Cellular phenolic (open cell)	1.8-2.2	0.23	—	4.40	—	—
Mineral fiber with resin binder	15.0	0.29	—	3.45	—	0.17
Mineral fiberboard, wet felted						
Core or roof insulation	16-17	0.34	—	2.94	—	—
Acoustical tile	18.0	0.35	—	2.86	—	0.19
Acoustical tile	21.0	0.37	—	2.70	—	—
Mineral fiberboard, wet molded						
Acoustical tile[l]	23.0	0.42	—	2.38	—	0.14
Wood or cane fiberboard						
Acoustical tile[l] 0.5 in.	—	—	0.80	—	1.25	0.31
Acoustical tile[l] 0.75 in.	—	—	0.53	—	1.89	—
Interior finish (plank, tile)	15.0	0.35	—	2.86	—	0.32
Cement fiber slabs (shredded wood with Portland cement binder)	25-27.0	0.50-0.53		2.0-1.89	—	
Cement fiber slabs (shredded wood with magnesia oxysulfide binder)	22.0	0.57	—	1.75	—	0.31
Loose Fill						
Cellulosic insulation (milled paper or wood pulp)	2.3-3.2	0.27-0.32	—	3.70-3.13	—	0.33
Perlite, expanded	2.0-4.1	0.27-0.31	—	3.7-3.3	—	0.26
	4.1-7.4	0.31-0.36	—	3.3-2.8	—	—
	7.4-11.0	0.36-0.42	—	2.8-2.4	—	—
Mineral fiber (rock, slag, or glass)[g]						
approx. 3.75-5 in.	0.6-2.0	—	—	—	11.0	0.17
approx. 6.5-8.75 in.	0.6-2.0	—	—	—	19.0	—
approx. 7.5-10 in.	0.6-2.0	—	—	—	22.0	—
approx. 10.25-13.75 in.	0.6-2.0	—	—	—	30.0	—
Mineral fiber (rock, slag, or glass)[g]						
approx. 3.5 in. (closed sidewall application)	2.0-3.5	—	—	—	12.0-14.0	—
Vermiculite, exfoliated	7.0-8.2	0.47	—	2.13	—	0.32
	4.0-6.0	0.44	—	2.27	—	—
Spray Applied						
Polyurethane foam	1.5-2.5	0.16-0.18	—	6.25-5.56	—	—
Ureaformaldehyde foam	0.7-1.6	0.22-0.28	—	4.55-3.57	—	—
Cellulosic fiber	3.5-6.0	0.29-0.34	—	3.45-2.94	—	—
Glass fiber	3.5-4.5	0.26-0.27	—	3.85-3.70	—	—
Reflective Insulation						
Reflective material ($\varepsilon < 0.5$) in center of 3/4 in. cavity forms two 3/8 in. vertical air spaces[m]	—	—	0.31	—	3.2	—
METALS (See Chapter 36, Table 3)						
ROOFING						
Asbestos-cement shingles	120	—	4.76	—	0.21	0.24
Asphalt roll roofing	70	—	6.50	—	0.15	0.36
Asphalt shingles	70	—	2.27	—	0.44	0.30
Built-up roofing 0.375 in.	70	—	3.00	—	0.33	0.35
Slate 0.5 in.	—	—	20.00	—	0.05	0.30
Wood shingles, plain and plastic film faced	—	—	1.06	—	0.94	0.31
PLASTERING MATERIALS						
Cement plaster, sand aggregate	116	5.0	—	0.20	—	0.20
Sand aggregate 0.375 in.	—	—	13.3	—	0.08	0.20
Sand aggregate 0.75 in.	—	—	6.66	—	0.15	0.20

Table 4 Typical Thermal Properties of Common Building and Insulating Materials—Design Values[a] (Continued)

Description	Density, lb/ft³	Conductivity[b] (k), Btu·in / h·ft²·°F	Conductance (C), Btu / h·ft²·°F	Resistance[c] (R): Per Inch Thickness (1/k), °F·ft²·h / Btu·in	Resistance[c] (R): For Thickness Listed (1/C), °F·ft²·h / Btu	Specific Heat, Btu / lb·°F
Gypsum plaster:						
Lightweight aggregate .... 0.5 in.	45	—	3.12	—	0.32	—
Lightweight aggregate .... 0.625 in.	45	—	2.67	—	0.39	—
Lightweight aggregate on metal lath .... 0.75 in.	—	—	2.13	—	0.47	—
Perlite aggregate	45	1.5	—	0.67	—	0.32
Sand aggregate	105	5.6	—	0.18	—	0.20
Sand aggregate .... 0.5 in.	105	—	11.10	—	0.09	—
Sand aggregate .... 0.625 in.	105	—	9.10	—	0.11	—
Sand aggregate on metal lath .... 0.75 in.	—	—	7.70	—	0.13	—
Vermiculite aggregate	45	1.7	—	0.59	—	—
MASONRY MATERIALS						
Masonry Units						
Brick, fired clay	150	8.4-10.2	—	0.12-0.10	—	—
	140	7.4-9.0	—	0.14-0.11	—	—
	130	6.4-7.8	—	0.16-0.12	—	—
	120	5.6-6.8	—	0.18-0.15	—	0.19
	110	4.9-5.9	—	0.20-0.17	—	—
	100	4.2-5.1	—	0.24-0.20	—	—
	90	3.6-4.3	—	0.28-0.24	—	—
	80	3.0-3.7	—	0.33-0.27	—	—
	70	2.5-3.1	—	0.40-0.33	—	—
Clay tile, hollow						
1 cell deep .... 3 in.	—	—	1.25	—	0.80	0.21
1 cell deep .... 4 in.	—	—	0.90	—	1.11	—
2 cells deep .... 6 in.	—	—	0.66	—	1.52	—
2 cells deep .... 8 in.	—	—	0.54	—	1.85	—
2 cells deep .... 10 in.	—	—	0.45	—	2.22	—
3 cells deep .... 12 in.	—	—	0.40	—	2.50	—
Concrete blocks[n, o]						
Limestone aggregate						
8 in., 36 lb, 138 lb/ft³ concrete, 2 cores	—	—	—	—	—	—
Same with perlite filled cores	—	—	0.48	—	2.1	—
12 in., 55 lb, 138 lb/ft³ concrete, 2 cores	—	—	—	—	—	—
Same with perlite filled cores	—	—	0.27	—	3.7	—
Normal weight aggregate (sand and gravel)						
8 in., 33-36 lb, 126-136 lb/ft³ concrete, 2 or 3 cores	—	—	0.90-1.03	—	1.11-0.97	0.22
Same with perlite filled cores	—	—	0.50	—	2.0	—
Same with vermiculite filled cores	—	—	0.52-0.73	—	1.92-1.37	—
12 in., 50 lb, 125 lb/ft³ concrete, 2 cores	—	—	0.81	—	1.23	0.22
Medium weight aggregate (combinations of normal weight and lightweight aggregate)						
8 in., 26-29 lb, 97-112 lb/ft³ concrete, 2 or 3 cores..	—	—	0.58-0.78	—	1.71-1.28	—
Same with perlite filled cores	—	—	0.27-0.44	—	3.7-2.3	—
Same with vermiculite filled cores	—	—	0.30	—	3.3	—
Same with molded EPS (beads) filled cores	—	—	0.32	—	3.2	—
Same with molded EPS inserts in cores	—	—	0.37	—	2.7	—
Lightweight aggregate (expanded shale, clay, slate or slag, pumice)						
6 in., 16-17 lb 85-87 lb/ft³ concrete, 2 or 3 cores	—	—	0.52-0.61	—	1.93-1.65	—
Same with perlite filled cores	—	—	0.24	—	4.2	—
Same with vermiculite filled cores	—	—	0.33	—	3.0	—
8 in., 19-22 lb, 72-86 lb/ft³ concrete	—	—	0.32-0.54	—	3.2-1.90	0.21
Same with perlite filled cores	—	—	0.15-0.23	—	6.8-4.4	—
Same with vermiculite filled cores	—	—	0.19-0.26	—	5.3-3.9	—
Same with molded EPS (beads) filled cores	—	—	0.21	—	4.8	—
Same with UF foam filled cores	—	—	0.22	—	4.5	—
Same with molded EPS inserts in cores	—	—	0.29	—	3.5	—
12 in., 32-36 lb, 80-90 lb/ft³ concrete, 2 or 3 cores...	—	—	0.38-0.44	—	2.6-2.3	—
Same with perlite filled cores	—	—	0.11-0.16	—	9.2-6.3	—
Same with vermiculite filled cores	—	—	0.17	—	5.8	—
Stone, lime, or sand	180	72	—	0.01	—	—
Quartzitic and sandstone	160	43	—	0.02	—	—
	140	24	—	0.04	—	—
	120	13	—	0.08	—	0.19
Calcitic, dolomitic, limestone, marble, and granite	180	30	—	0.03	—	—
	160	22	—	0.05	—	—
	140	16	—	0.06	—	—
	120	11	—	0.09	—	0.19
	100	8	—	0.13	—	—

Table 4 Typical Thermal Properties of Common Building and Insulating Materials—Design Values[a] (Continued)

				Resistance[c] (R)		
Description	Density, lb/ft³	Conductivity[b] (k), Btu·in / h·ft²·°F	Conductance (C), Btu / h·ft²·°F	Per Inch Thickness (1/k), °F·ft²·h / Btu·in	For Thickness Listed (1/C), °F·ft²·h / Btu	Specific Heat, Btu / lb·°F
Gypsum partition tile						
3 by 12 by 30 in., solid	—	—	0.79	—	1.26	0.19
3 by 12 by 30 in., 4 cells	—	—	0.74	—	1.35	—
4 by 12 by 30 in., 3 cells	—	—	0.60	—	1.67	—
Concretes[d]						
Sand and gravel or stone aggregate concretes (concretes with more than 50% quartz or quartzite sand have conductivities in the higher end of the range)	150	10.0-20.0	—	0.10-0.05	—	—
	140	9.0-18.0	—	0.11-0.06	—	0.19-0.24
	130	7.0-13.0	—	0.14-0.08	—	—
Limestone concretes	140	11.1	—	0.09	—	—
	120	7.9	—	0.13	—	—
	100	5.5	—	0.18	—	—
Gypsum-fiber concrete (87.5% gypsum, 12.5% wood chips)	51	1.66	—	0.60	—	0.21
Cement/lime, mortar, and stucco	120	9.7	—	0.10	—	—
	100	6.7	—	0.15	—	—
	80	4.5	—	0.22	—	—
Lightweight aggregate concretes						
Expanded shale, clay, or slate; expanded slags; cinders; pumice (with density up to 100 lb/ft³); and scoria (sanded concretes have conductivities in the higher end of the range)	120	6.4-9.1	—	0.16-0.11	—	—
	100	4.7-6.2	—	0.21-0.16	—	0.20
	80	3.3-4.1	—	0.30-0.24	—	0.20
	60	2.1-2.5	—	0.48-0.40	—	—
	40	1.3	—	0.78	—	—
Perlite, vermiculite, and polystyrene beads	50	1.8-1.9	—	0.55-0.53	—	—
	40	1.4-1.5	—	0.71-0.67	—	0.15-0.23
	30	1.1	—	0.91	—	—
	20	0.8	—	1.25	—	—
Foam concretes	120	5.4	—	0.19	—	—
	100	4.1	—	0.24	—	—
	80	3.0	—	0.33	—	—
	70	2.5	—	0.40	—	—
Foam concretes and cellular concretes	60	2.1	—	0.48	—	—
	40	1.4	—	0.71	—	—
	20	0.8	—	1.25	—	—
SIDING MATERIALS (on flat surface)						
Shingles						
Asbestos-cement	120	—	4.75	—	0.21	—
Wood, 16 in., 7.5 exposure	—	—	1.15	—	0.87	0.31
Wood, double, 16-in., 12-in. exposure	—	—	0.84	—	1.19	0.28
Wood, plus ins. backer board, 0.312 in.	—	—	0.71	—	1.40	0.31
Siding						
Asbestos-cement, 0.25 in., lapped	—	—	4.76	—	0.21	0.24
Asphalt roll siding	—	—	6.50	—	0.15	0.35
Asphalt insulating siding (0.5 in. bed.)	—	—	0.69	—	1.46	0.35
Hardboard siding, 0.4375 in.	—	—	1.49	—	0.67	0.28
Wood, drop, 1 by 8 in.	—	—	1.27	—	0.79	0.28
Wood, bevel, 0.5 by 8 in., lapped	—	—	1.23	—	0.81	0.28
Wood, bevel, 0.75 by 10 in., lapped	—	—	0.95	—	1.05	0.28
Wood, plywood, 0.375 in., lapped	—	—	1.69	—	0.59	0.29
Aluminum, steel, or vinyl[p,q], over sheathing						
Hollow-backed	—	—	1.64	—	0.61	0.29[q]
Insulating-board backed nominal 0.375 in.	—	—	0.55	—	1.82	0.32
Insulating-board backed nominal 0.375 in., foil backed	—	—	0.34	—	2.96	—
Architectural (soda-lime float) glass	158	6.9	—	—	—	0.21
WOODS (12% moisture content)[e,r]						
Hardwoods						0.39[s]
Oak	41.2-46.8	1.12-1.25	—	0.89-0.80	—	
Birch	42.6-45.4	1.16-1.22	—	0.87-0.82	—	
Maple	39.8-44.0	1.09-1.19	—	0.92-0.84	—	
Ash	38.4-41.9	1.06-1.14	—	0.94-0.88	—	
Softwoods						0.39[s]
Southern Pine	35.6-41.2	1.00-1.12	—	1.00-0.89	—	
Douglas Fir-Larch	33.5-36.3	0.95-1.01	—	1.06-0.99	—	
Southern Cypress	31.4-32.1	0.90-0.92	—	1.11-1.09	—	
Hem-Fir, Spruce-Pine-Fir	24.5-31.4	0.74-0.90	—	1.35-1.11	—	
West Coast Woods, Cedars	21.7-31.4	0.68-0.90	—	1.48-1.11	—	
California Redwood	24.5-28.0	0.74-0.82	—	1.35-1.22	—	

Notes for Table 4

[a]Values are for a mean temperature of 75°F. Representative values for dry materials are intended as design (not specification) values for materials in normal use. Thermal values of insulating materials may differ from design values depending on their in-situ properties (e.g., density and moisture content, orientation, etc.) and variability experienced during manufacture. For properties of a particular product, use the value supplied by the manufacturer or by unbiased tests.

[b]To obtain thermal conductivities in Btu/h·ft·°F, divide the k-factor by 12 in/ft.

[c]Resistance values are the reciprocals of C before rounding off C to two decimal places.

[d]Lewis (1967).

[e]U.S. Department of Agriculture (1974).

[f]Does not include paper backing and facing, if any. Where insulation forms a boundary (reflective or otherwise) of an airspace, see Tables 2 and 3 for the insulating value of an airspace with the appropriate effective emittance and temperature conditions of the space.

[g]Conductivity varies with fiber diameter. (See Chapter 22, Factors Affecting Thermal Performance.) Batt, blanket, and loose-fill mineral fiber insulations are manufactured to achieve specified R-values, the most common of which are listed in the table. Due to differences in manufacturing processes and materials, the product thicknesses, densities, and thermal conductivities vary over considerable ranges for a specified R-value.

[h]This material is relatively new and data are based on limited testing.

[i]For additional information, see Society of Plastics Engineers (SPI) *Bulletin* U108. Values are for aged, unfaced board stock. For change in conductivity with age of expanded polyurethane/polyisocyanurate, see Chapter 22, Factors Affecting Thermal Performance.

[j]Values are for aged products with gas-impermeable facers on the two major surfaces. An aluminum foil facer of 0.001 in. thickness or greater is generally considered impermeable to gases. For change in conductivity with age of expanded polyisocyanurate, see Chapter 22, Factors Affecting Thermal Performance, and SPI *Bulletin* U108.

[k]Cellular phenolic insulation may no longer be manufactured. The thermal conductivity and resistance values do not represent aged insulation, which may have a higher thermal conductivity and lower thermal resistance.

[l]Insulating values of acoustical tile vary, depending on density of the board and on type, size, and depth of perforations.

[m]Cavity is framed with 0.75 in. wood furring strips. Caution should be used in applying this value for other framing materials. The reported value was derived from tests and applies to the reflective path only. The effect of studs or furring strips must be included in determining the overall performance of the wall.

[n]Values for fully grouted block may be approximated using values for concrete with a similar unit weight.

[o]Values for concrete block and concrete are at moisture contents representative of normal use.

[p]Values for metal or vinyl siding applied over flat surfaces vary widely, depending on amount of ventilation of airspace beneath the siding; whether airspace is reflective or nonreflective; and on thickness, type, and application of insulating backing used. Values are averages for use as design guides, and were obtained from several guarded hot box tests (ASTM C 236) or calibrated hot box (ASTM C 976) on hollow-backed types and types made using backing-boards of wood fiber, foamed plastic, and glass fiber. Departures of ±50% or more from these values may occur.

[q]Vinyl specific heat = 0.25 Btu/lb·°F

[r]See Adams (1971), MacLean (1941), and Wilkes (1979). The conductivity values listed are for heat transfer across the grain. The thermal conductivity of wood varies linearly with the density, and the density ranges listed are those normally found for the wood species given. If the density of the wood species is not known, use the mean conductivity value. For extrapolation to other moisture contents, the following empirical equation developed by Wilkes (1979) may be used:

$$k = 0.1791 + \frac{(1.874 \times 10^{-2} + 5.753 \times 10^{-4} M)\rho}{1 + 0.01M}$$

where ρ is density of the moist wood in lb/ft³, and M is the moisture content in percent.

[s]From Wilkes (1979), an empirical equation for the specific heat of moist wood at 75°F is as follows:

$$c_p = \frac{(0.299 + 0.01M)}{(1 + 0.01M)} + \Delta c_p$$

where Δc_p accounts for the heat of sorption and is denoted by

$$\Delta c_p = M(1.921 \times 10^{-3} - 3.168 \times 10^{-5} M)$$

where M is the moisture content in percent by mass.

Example 1. Calculate the U-factor of the 2 by 4 stud wall shown in Figure 2. The studs are at 16 in. OC. There is 3.5 in. mineral fiber batt insulation (R-13) in the stud space. The inside finish is 0.5 in. gypsum wallboard; the outside is finished with rigid foam insulating sheathing (R-4) and 0.5 in. by 8 in. wood bevel lapped siding. The insulated cavity occupies approximately 75% of the transmission area; the studs, plates, and sills occupy 21%; and the headers occupy 4%.

Solution. Obtain the R-values of the various building elements from Tables 1 and 4. Assume the R = 1.25 per inch for the wood framing. Also, assume the headers are solid wood, in this case, and group them with the studs, plates, and sills.

Element	*R* (Insulated Cavity)	*R* (Studs, Plates, and Headers)
1. Outside surface, 15 mphwind	0.17	0.17
2. Wood bevel lapped siding	0.81	0.81
3. Rigid foam insulating sheathing	4.0	4.0
4. Mineral fiber batt insulation, 3.5 in.	13.0	—
5. Wood stud, nominal 2 × 4	—	4.38
6. Gypsum wallboard, 0.5 in.	0.45	0.45
7. Inside surface, still air	0.68	0.68
	$R_1 = 19.11$	$R_2 = 10.49$

Since the U-factor is the reciprocal of R-value, $U_1 = 0.052$ and $U_2 = 0.095$ Btu/h·ft²·°F.

If the wood framing (thermal bridging) is not included, Equation (3) from Chapter 22 may be used to calculate the U-factor of the wall as follows:

$$U_{av} = U_1 = \frac{1}{R_1} = 0.052 \text{ Btu/h} \cdot \text{ft}^2 \cdot {}^\circ\text{F}$$

If the wood framing is accounted for using the parallel-path flow method, the U-factor of the wall is determined using Equation (5) from Chapter 22 as follows:

$$U_{av} = (0.75 \times 0.052) + (0.25 \times 0.095) = 0.063 \text{ Btu/h} \cdot \text{ft}^2 \cdot {}^\circ\text{F}$$

If the wood framing is included using the isothermal planes method, the U-factor of the wall is determined using Equations (2) and (3) from Chapter 22 as follows:

$$R_{T(av)} = 4.98 + 1/[(0.75/13.0) + (0.25/4.38)] + 1.13$$

$$= 14.82{}^\circ\text{F} \cdot \text{ft}^2 \cdot \text{h/Btu}$$

$$U_{av} = 0.067 \text{ Btu/h} \cdot \text{ft}^2 \cdot {}^\circ\text{F}$$

For a frame wall with a 24-in. OC stud space, the average overall R-value is 15.18°F·ft²·h/Btu. Similar calculation procedures may be used to evaluate other wall designs, except those with thermal bridges.

Masonry Walls

The average overall R-values of masonry walls can be estimated by assuming a combination of layers in series, one or more of which provides parallel paths. This method is used because heat flows laterally through block face shells so that transverse isothermal planes result. Average total resistance $R_{T(av)}$ is the sum of the resistances of the layers between such planes, each layer calculated as shown in Example 2.

Example 2. Calculate the overall thermal resistance and average U-factor of the 7-5/8-in. thick insulated concrete block wall shown in Figure 3. The two-core block has an average web thickness of 1-in. and a face shell thickness of 1-1/4-in. Overall block dimensions are 7-5/8 by 7-5/8 by 15-5/8 in. Measured thermal resistances of 112 lb/ft^3 concrete and 7 lb/ft^3 expanded perlite insulation are 0.10 and 2.90°F·ft^2·h/Btu per inch, respectively.

Solution. The equation used to determine the overall thermal resistance of the insulated concrete block wall is derived from Equations (2) and (5) from Chapter 22 and is given below:

$$R_{T(av)} = R_i + R_f + \left(\frac{a_w}{R_w} + \frac{a_c}{R_c}\right)^{-1} + R_o$$

where

$R_{T(av)}$ = overall thermal resistance based on assumption of isothermal planes
R_i = thermal resistance of inside air surface film (still air)
R_o = thermal resistance of outside air surface film (15 mph wind)
R_f = total thermal resistance of face shells
R_c = thermal resistance of cores between face shells
R_w = thermal resistance of webs between face shells
a_w = fraction of total area transverse to heat flow represented by webs of blocks
a_c = fraction of total area transverse to heat flow represented by cores of blocks

From the information given and the data in Table 1, determine the values needed to compute the overall thermal resistance.

R_i = 0.68
R_o = 0.17
R_f = (2)(1.25)(0.10) = 0.25
R_c = (5.125)(2.90) = 14.86
R_w = (5.125)(0.10) = 0.51
a_w = 3/15.625 = 0.192
a_c = 12.625/15.625 = 0.808

Using the equation given, the overall thermal resistance and average U-factor are calculated as follows:

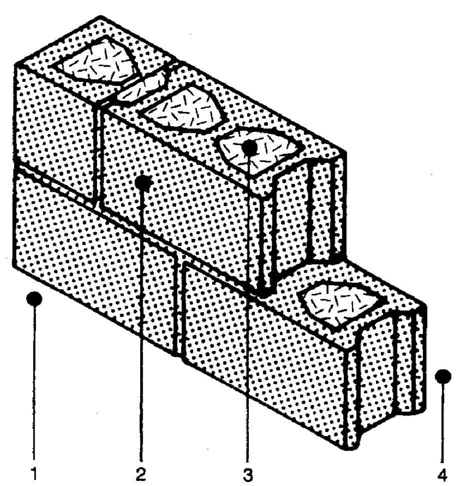


Fig. 3 Insulated Concrete Block Wall (Example 2)

$$R_{T(av)} = 0.68 + 0.25 + \frac{0.51 \times 14.86}{(0.808 \times 0.51) + (0.192 \times 14.86)} + 0.17$$

$$= 3.43\text{°F} \cdot \text{ft}^2 \cdot \text{h/Btu}$$

$$U_{av} = 1/3.43 = 0.29 \text{ Btu/h} \cdot \text{ft}^2 \cdot \text{°F}$$

Based on guarded hot box tests of this wall without mortar joints, Tye and Spinney (1980) measured the average R-value for this insulated concrete block wall as 3.13°F·ft^2·h/Btu.

Assuming parallel heat flow only, the calculated resistance is higher than that calculated on the assumption of isothermal planes. The actual resistance generally is some value between the two calculated values. In the absence of test values, examination of the construction usually reveals whether a value closer to the higher or lower calculated R-value should be used. Generally, if the construction contains a layer in which lateral conduction is high compared with transmittance through the construction, the calculation with isothermal planes should be used. If the construction has no layer of high lateral conductance, the parallel heat flow calculation should be used.

Hot box tests of insulated and uninsulated masonry walls constructed with block of conventional configuration show that thermal resistances calculated using the isothermal planes heat flow method agree well with measured values (Van Geem 1985, Valore 1980, Shu et al. 1979). Neglecting horizontal mortar joints in conventional block can result in thermal transmittance values up to 16% lower than actual, depending on the density and thermal properties of the masonry, and 1 to 6% lower, depending on the core insulation material (Van Geem 1985, McIntyre 1984). For aerated concrete block walls, other solid masonry, and multicore block walls with full mortar joints, neglecting mortar joints can cause errors in R-values up to 40% (Valore 1988). Horizontal mortar joints usually found in concrete block wall construction are neglected in Example 2.

Constructions Containing Metal

Curtain and metal stud-wall constructions often include metallic and other thermal bridges, which can significantly reduce the thermal resistance. However, the capacity of the adjacent facing materials to transmit heat transversely to the metal is limited, and some contact resistance between all materials in contact limits the reduction. Contact resistances in building structures are only 0.06 to 0.6°F·ft^2·h/Btu—too small to be of concern in many cases. However, the contact resistances of steel framing members may be important. Also, in many cases (as illustrated in Example 3), the area of metal in contact with the facing greatly exceeds the thickness of the metal, which mitigates the contact reistance effects.

Thermal characteristics for panels of sandwich construction can be computed by combining the thermal resistances of the various layers. However, few panels are true sandwich constructions; many have ribs and stiffeners that create complicated heat flow paths. R-values for the assembled sections should be determined on a representative sample by using a hot box method. If the sample is a wall section with air cavities on both sides of fibrous insulation, the sample must be of representative height since convective airflow can contribute significantly to heat flow through the test section. Computer modeling can also be useful, but all heat transfer mechanisms must be considered.

In Example 3, the metal member is only 0.020 in. thick, but it is in contact with adjacent facings over a 1.25 in.-wide area. The steel member is 3.50 in. deep, has a thermal resistance of approximately 0.011°F·ft^2·h/Btu, and is virtually isothermal. The calculation involves careful selection of the appropriate thickness for the steel member. If the member is assumed to be 0.020 in. thick, the fact that the flange transmits heat to the adjacent facing is ignored, and the heat flow through the steel is underestimated. If the member is assumed to be 1.25 in. thick, the heat flow through the steel is overestimated. In Example 3, the steel member behaves in much the same way as a rectangular member 1.25 in. thick and 3.50 in. deep with a thermal resistance of (1.25/0.020) × 0.011 = 0.69°F·ft²·h/Btu does. The Building Research Association of New Zealand (BRANZ) commonly uses this approximation.

Example 3. Calculate the C-factor of the insulated steel frame wall shown in Figure 4. Assume that the steel member has an R-value of 0.69°F·ft²·h/Btu and that the framing behaves as though it occupies approximately 8% of the transmission area.

Solution. Obtain the R-values of the various building elements from Table 4.

Element	*R* (Insul.)	*R* (Framing)
1. 0.5-in. gypsum wallboard	0.45	0.45
2. 3.5-in. mineral fiber batt insulation	11	—
3. Steel framing member	—	0.69
4. 0.5-in. gypsum wallboard	0.45	0.45
	$R_1 = 11.90$	$R_2 = 1.59$

Therefore, $C_1 = 0.084$; $C_2 = 0.629$ Btu/h·ft²·°F.

If the steel framing (thermal bridging) is not considered, the C-factor of the wall is calculated using Equation (3) from Chapter 22 as follows:

$$C_{av} = C_1 = 1/R_1 = 0.084 \text{ Btu/h} \cdot \text{ft}^2 \cdot {}^\circ\text{F}$$

If the steel framing is accounted for using the parallel flow method, the C-factor of the wall is determined using Equation (5) from Chapter 22 as follows:

$$C_{av} = (0.92 \times 0.084) + (0.08 \times 0.629)$$
$$= 0.128 \text{ Btu/h} \cdot \text{ft}^2 \cdot {}^\circ\text{F}$$
$$R_{T(av)} = 7.81\,{}^\circ\text{F} \cdot \text{ft}^2 \cdot \text{h/Btu}$$

If the steel framing is included using the isothermal planes method, the C-factor of the wall is determined using Equations (2) and (3) from Chapter 22 as follows:

$$R_{T(av)} = 0.45 + 1/[(0.92/11.00) + (0.08/0.69)] + 0.45$$
$$= 5.91\,{}^\circ\text{F} \cdot \text{ft}^2 \cdot \text{h/Btu}$$
$$C_{av} = 0.169 \text{ Btu/h} \cdot \text{ft}^2 \cdot {}^\circ\text{F}$$

For this insulated steel frame wall, Farouk and Larson (1983) measured an average R-value of 6.61°F·ft²·h/Btu.

In ASHRAE/IESNA *Standard* 90.1-1989, one method given for determining the thermal resistance of wall assemblies containing metal framing involves using a parallel path correction factor F_c, which is listed in Table 8C-2 of the standard. For 2 by 4 steel framing, 16 in. OC, $F_c = 0.50$. Using the correction factor method, an R-value of 6.40°F·ft²·h/Btu [0.45 + 11(0.50) + 0.45] is obtained for the wall described in Example 3.

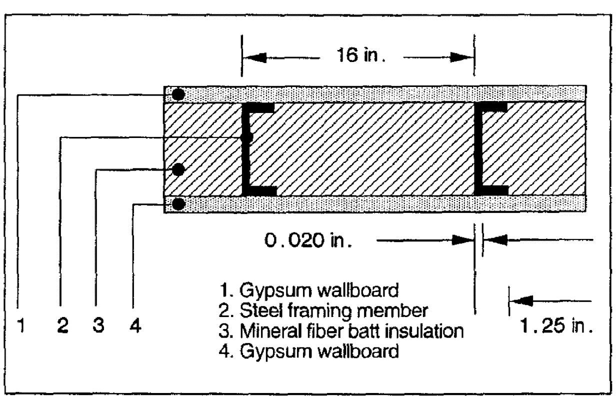


Fig. 4 Insulated Steel Frame Wall (Example 3)

Zone Method of Calculation

For structures with widely spaced metal members of substantial cross-sectional area, calculation by the isothermal planes method can result in thermal resistance values that are too low. For these constructions, the **zone method** can be used. This method involves two separate computations—one for a chosen limited portion, Zone A, containing the highly conductive element; the other for the remaining portion of simpler construction, Zone B. The two computations are then combined using the parallel flow method, and the average transmittance per unit overall area is calculated. The basic laws of heat transfer are applied by adding the area conductances *CA* of elements in parallel, and adding area resistances *R*/*A* of elements in series.

The surface shape of Zone A is determined by the metal element. For a metal beam (see Figure 5), the Zone A surface is a strip of width *W* that is centered on the beam. For a rod perpendicular to panel surfaces, it is a circle of diameter *W*. The value of *W* is calculated from Equation (1), which is empirical. The value of *d* should not be less than 0.5 in. for still air.

$$W = m + 2d \qquad (1)$$

where

m = width or diameter of metal heat path terminal, in.
d = distance from panel surface to metal, in.

Generally, the value of *W* should be calculated using Equation (1) for each end of the metal heat path; the larger value, within the limits of the basic area, should be used as illustrated in Example 4.

Example 4. Calculate transmittance of the roof deck shown in Figure 5. Tee-bars at 24 in. OC support glass fiber form boards, gypsum concrete, and built-up roofing. Conductivities of components are: steel, 314.4 Btu·in/h·ft²·°F; gypsum concrete, 1.66 Btu·in/h·ft²·°F; and glass fiber form board, 0.25 Btu·in/h·ft²·°F. Conductance of built-up roofing is 3.00 Btu/h·ft²·°F.

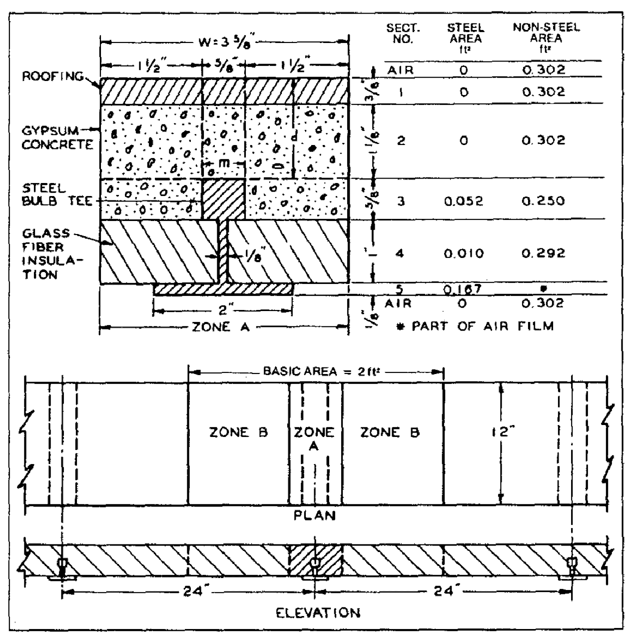


Fig. 5 Gypsum Roof Deck on Bulb Tees (Example 4)

Solution. The basic area is 2 ft^2 (24 in. by 12 in.) with a tee-bar (12 in. long) across the middle. This area is divided into Zones A and B.

Zone A is determined from Equation (1) as follows:

$$\text{Top side } W = m + 2d = 0.625 + (2 \times 1.5) = 3.625 \text{ in.}$$

$$\text{Bottom side } W = m + 2d = 2.0 + (2 \times 0.5) = 3.0 \text{ in.}$$

Using the larger value of W, the area of Zone A is $(12 \times 3.625)/144 = 0.302$ ft^2. The area of Zone B is $2.0 - 0.302 = 1.698$ ft^2.

To determine area transmittance for Zone A, divide the structure within the zone into five sections parallel to the top and bottom surfaces (Figure 5). The area conductance CA of each section is calculated by adding the area conductances of its metal and nonmetal paths. Area conductances of the sections are converted to area resistances R/A and added to obtain the total resistance of Zone A.

Section	Area × Conductance =	CA	$\frac{1}{CA} = \frac{R}{A}$
Air (outside, 15 mph)	0.302 × 6.00	1.81	0.55
No. 1, Roofing	0.302 × 3.00	0.906	1.10
No. 2, Gypsum concrete	0.302 × 1.66/1.125	0.446	2.24
No. 3, Steel	0.052 × 314.4/0.625	26.2	0.04
No. 3, Gypsum concrete	0.250 × 1.66/0.625	0.664	
No. 4, Steel	0.010 × 314.4/1.00	3.14	0.31
No. 4, Glass fiberboard	0.292 × 0.25/1.00	0.073	
No. 5, Steel	0.167 × 314.4/0.125	420.0	0.002
Air (inside)	0.302 × 1.63	0.492	2.03
		Total R/A =	6.27

Area transmittance of Zone A = $1/(R/A) = 1/6.27 = 0.159$.

For Zone B, the unit resistances are added and then converted to area transmittance, as shown in the following table.

Section	Resistance, R
Air (outside, 15 mph)	1/6.00 = 0.17
Roofing	1/3.00 = 0.33
Gypsum concrete	1.75/1.66 = 1.05
Glass fiberboard	1.00/0.25 = 4.00
Air (inside)	1/1.63 = 0.61
Total resistance	= 6.16

Since unit transmittance = $1/R = 0.162$, the total area transmittance UA is calculated as follows:

$$\begin{aligned} \text{Zone B} = 1.698 \times 0.162 &= 0.275 \\ \text{Zone A} &= \underline{0.159} \\ \text{Total area transmittance of basic area} &= 0.434 \\ \text{Transmittance per ft}^2 = 0.434/2.0 &= 0.217 \\ \text{Resistance per ft}^2 &= 4.61 \end{aligned}$$

Overall R-values of 4.57 and 4.85°F·ft²·h/Btu have been measured in two guarded hot box tests of a similar construction.

When the steel member represents a relatively large proportion of the total heat flow path, as in Example 4, detailed calculations of resistance in sections 3, 4, and 5 of Zone A are unnecessary; if only the steel member is considered, the final result of Example 4 is the same. However, if the heat flow path represented by the steel member is small, as for a tie rod, detailed calculations for sections 3, 4, and 5 are necessary. A panel with an internal metallic structure and bonded on one or both sides to a metal skin or covering presents special problems of lateral heat flow not covered in the zone method.

Modified Zone Method for Metal Stud Walls with Insulated Cavities

The modified zone method is similar to the parallel path method and the zone method. All three methods are based on parallel-path calculations. Figure 6 shows the width w of the zone of thermal anomalies around a metal stud. This zone can be assumed to equal the length of the stud flange L (parallel path method), or can be calculated as a sum of the length of stud flange and a distance double that from wall surface to metal Σd_i (zone method). In the modified zone method the width of the zone depends on the following three parameters:

- Ratio between thermal resistivity of sheathing material and cavity insulation
- Size (depth) of stud
- Thickness of sheathing material

The Modified Zone Method is explained in Figure 6 (which can be copied and used as a calculation form). The wall cross section shown in Figure 6, is divided into two zones: the zone of thermal anomalies around metal stud w and the cavity zone cav. Wall material layers are grouped into an exterior and interior surface sections—A (sheathing, siding) and B (wallboard)—and interstitial sections I and II (cavity insulation, metal stud flange).

Assuming that the layers or layer of wall materials in wall section A are thicker than those in wall section B, as show by the cross section in Figure 6, they can be described as follows:

$$\sum_{i=1}^{n} d_i \geq \sum_{j=1}^{m} d_j \qquad (2)$$

where

n = number of material layer (of thickness d_i) between metal stud flange and wall surface for section A
m = number of material layer (of thickness d_j) for section B

Then, the width of the zone of thermal anomalies around the metal stud w can be estimated by

$$w = L + z_f \sum_{i=1}^{n} d_i \qquad (3)$$

where

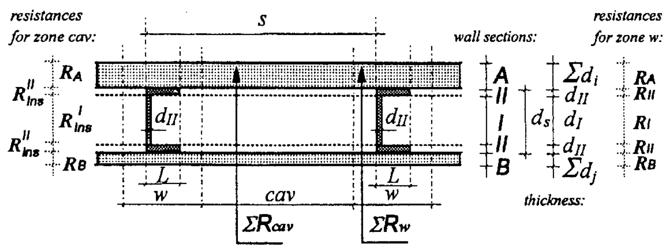
L = stud flange size,
d_i = thickness of material layer in section A
z_f = zone factor, which is shown in Figure 7 ($z_f = 2$ for zone method)

Kosny and Christian (1995) verified the accuracy of the Modified Zone Method for over 200 simulated cases of metal frame walls with insulated cavities. For all configurations considered the discrepancy between results were within ±2%. Hot box measured R-values for 15 metal stud walls tested by Barbour et al. (1994) were compared with results obtained by Kosny and Christian (1995) and McGowan and Desjarlais (1997). The Modified Zone Method was found to be the most accurate simple method for estimating the clear wall R-value of light-gage steel stud walls with insulated cavities. However, this analysis does not apply to construction with metal sheathing. Also, *ASHRAE Standard* 90.1 may require a different method of analysis.

Ceilings and Roofs

The overall R-value for ceilings of wood frame flat roofs can be calculated using Equations (1) through (5) from Chapter 22. Properties of the materials are found in Tables 1, 3, 2, and 4. The fraction of framing is assumed to be 0.10 for joists at 16 in. OC and 0.07 for joists at 24 in. OC. The calculation procedure is similar to that shown in Example 1. Note that if the ceiling contains plane air spaces (see Table 3), the resistance depends on the direction of heat flow, i.e., whether the calculation is for a winter (heat flow up) or summer (heat flow down) condition.

For ceilings of pitched roofs under winter conditions, calculate the R-value of the ceiling using the procedure for flat roofs. Table 5 can be used to determine the effective resistance of the



Wall Section	Material	Thick-ness, in.	Resistivity, h·ft²·°F/Btu·in
A		d_{i1} =	r_1 =
A		d_{i2} =	r_2 =
A		d_{i3} =	r_3 =
B		d_{j1} =	r_{j1} =
I & II	Metal	d_{II} =	r_{met}
I & II	Cavity insulation	d_s =	r_{ins}

$s =$ .... ; $d_I = d_s - 2 \times d_{II} =$ ....

$\dfrac{\text{resistivity of sheathing}}{\text{resistivity of cav. insul.}} =$ ....

z_f *(from Zone Factor Chart)* = ...

$w = L + z_f \times \Sigma d_i =$ ....

$R_A = \Sigma(r_i \times d_i) =$ ....

$R_B = \Sigma(r_j \times d_j) =$ ....

$R^{I}_{ins} = r_{ins} \times d_I =$ ....

$R^{II}_{ins} = r_{ins} \times d_{II} =$ ....

$R^{I}_{met} = r_{met} \times d_I =$ ....

$R^{II}_{met} = r_{met} \times d_{II} =$ ....

$$R_I = \frac{R^{I}_{met} \times R^{I}_{ins} \times w}{d_{II} \times (R^{I}_{ins} - R^{I}_{met}) + w \times R^{I}_{met}} = \frac{\quad}{\quad} = \text{........}$$

$$R_{II} = \frac{R^{II}_{met} \times R^{II}_{ins} \times w}{L \times (R^{II}_{ins} - R^{II}_{met}) + w \times R^{II}_{met}} = \frac{\quad}{\quad} = \text{........}$$

$\Sigma R_{cav} = R_A + R_B + R^{I}_{ins} + 2 \times R^{II}_{ins} =$ ....

$\Sigma R_w = R_A + R_B + R_I + 2 \times R_{II} =$ ....

$$R_{tot} = \frac{\Sigma R_w \times \Sigma R_{cav} \times s}{w \times (\Sigma R_{cav} - \Sigma R_w) + s \times \Sigma R_w} = \frac{\quad}{\quad} =$$

Fig. 6 Modified Zone Method R-Value Calculation Form for Metal Stud Walls

attic space under summer conditions for varying conditions of ventilation air temperature, airflow direction and rates, ceiling resistance, roof or sol-air temperatures, and surface emittances (Joy 1958).

The R-value is the total resistance obtained by adding the ceiling and effective attic resistances. The applicable temperature difference is that difference between room air and sol-air temperatures or between room air and roof temperatures (see Table 5, footnote f). Table 5 can be used for pitched and flat residential roofs over attic spaces. When an attic has a floor, the ceiling resistance should account for the complete ceiling-floor construction.

Windows and Doors

Table 5 of Chapter 29 lists U-factors for various fenestration products. Table 6 in Chapter 29 lists U-factors for exterior wood and steel doors. All U-factors are approximate, because a significant portion of the resistance of a window or door is contained in the air film resistances, and some parameters that may have important effects are not considered. For example, the listed U-factors assume the surface temperatures of surrounding bodies are equal to the ambient air temperature. However, the indoor surface of a window or door in an actual installation may be exposed to nearby radiating surfaces, such as radiant heating panels, or opposite walls with much higher or lower temperatures than the indoor air. Air movement across the indoor surface of a window or door, such as that caused by nearby heating and cooling outlet grilles, increases the U-factor; and air movement (wind) across the outdoor surface of a window or door also increases the U-factor.

U_o Concept

U_o is the combined thermal transmittance of the respective areas of gross exterior wall, roof or ceiling or both, and floor assemblies. The U_o equation for a wall is as follows:

$$U_o = (U_{wall}A_{wall} + U_{window}A_{window} + U_{door}A_{door})/A_o \quad (4)$$

where

U_o = average thermal transmittance of gross wall area
A_o = gross area of exterior walls
U_{wall} = thermal transmittance of all elements of opaque wall area
A_{wall} = opaque wall area
U_{window} = thermal transmittance of window area (including frame)
A_{window} = window area (including frame)
U_{door} = thermal transmittance of door area
A_{door} = door area (including frame)

Where more than one type of wall, window, or door is used, the UA term for that exposure should be expanded into its subelements, as shown in Equation (3).

$$\begin{aligned} U_oA_o = {} & U_{wall\,1}A_{wall\,1} + U_{wall\,2}A_{wall\,2} + \dots + U_{wall\,m}A_{wall\,m} \\ & + U_{window\,1}A_{window\,1} + U_{window\,2}A_{window\,2} + \dots \\ & + U_{window\,n}A_{window\,n} + U_{door\,1}A_{door\,1} \\ & + U_{door\,2}A_{door\,2} + \dots + U_{door\,o}A_{door\,o} \end{aligned} \quad (5)$$

Table 5 Effective Thermal Resistance of Ventilated Attics[a] (Summer Condition)

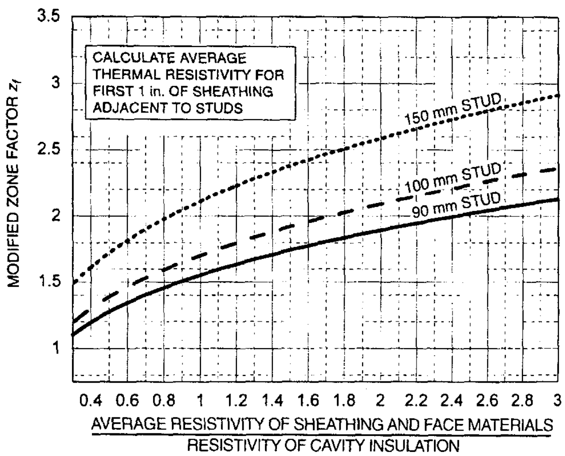
		No Ventilation[b]		Natural Ventilation		Power Ventilation[c]					
		Ventilation Rate, cfm/ft²									
		0		0.1[d]		0.5		1.0		1.5	
Ventilation Air Temperature, °F	Sol-Air[f] Temperature, °F	Ceiling Resistance R^e, °F·ft²·/Btu									
		10	20	10	20	10	20	10	20	10	20
NONREFLECTIVE SURFACES											
	120	1.9	1.9	2.8	3.4	6.3	9.3	9.6	16	11	20
80	140	1.9	1.9	2.8	3.5	6.5	10	9.8	17	12	21
	160	1.9	1.9	2.8	3.6	6.7	11	10	18	13	22
	120	1.9	1.9	2.5	2.8	4.6	6.7	6.1	10	6.9	13
90	140	1.9	1.9	2.6	3.1	5.2	7.9	7.6	12	8.6	15
	160	1.9	1.9	2.7	3.4	5.8	9.0	8.5	14	10	17
	120	1.9	1.9	2.2	2.3	3.3	4.4	4.0	6.0	4.1	6.9
100	140	1.9	1.9	2.4	2.7	4.2	6.1	5.8	8.7	6.5	10
	160	1.9	1.9	2.6	3.2	5.0	7.6	7.2	11	8.3	13
REFLECTIVE SURFACES[g]											
	120	6.5	6.5	8.1	8.8	13	17	17	25	19	30
80	140	6.5	6.5	8.2	9.0	14	18	18	26	20	31
	160	6.5	6.5	8.3	9.2	15	18	19	27	21	32
	120	6.5	6.5	7.5	8.0	10	13	12	17	13	19
90	140	6.5	6.5	7.7	8.3	12	15	14	20	16	22
	160	6.5	6.5	7.9	8.6	13	16	16	22	18	25
	120	6.5	6.5	7.0	7.4	8.0	10	8.5	12	8.8	12
100	140	6.5	6.5	7.3	7.8	10	12	11	15	12	16
	160	6.5	6.5	7.6	8.2	11	14	13	18	15	20

[a]Although the term *effective resistance* is commonly used when there is attic ventilation, this table includes values for situations with no ventilation. The effective resistance of the attic added to the resistance ($1/U$) of the ceiling yields the effective resistance of this combination based on sol-air (see Chapter 28) and room temperatures. These values apply to wood frame construction with a roof deck and roofing that has a conductance of 1.0 Btu/h·ft²·°F.
[b]This condition cannot be achieved in the field unless extreme measures are taken to tightly seal the attic.
[c]Based on air discharging outward from attic.
[d]When attic ventilation meets the requirements stated in Chapter 25, 0.1 cfm/ft² is assumed as the natural summer ventilation rate.
[e]When determining ceiling resistance, do not add the effect of a reflective surface facing the attic, as it is accounted for in the Reflective Surfaces part of the table.
[f]Roof surface temperature rather than sol-air temperature (see Chapter 28) can be used if 0.25 is subtracted from the attic resistance shown.
[g]Surfaces with effective emittance $\varepsilon_{eff} = 0.05$ between ceiling joists facing attic space.

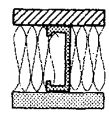
Table 6 Transmission Coefficients U for Wood and Steel Doors, Btu/h·ft²·°F

Nominal Door Thickness, in.	Description	No Storm Door	Wood Storm Door[c]	Metal Storm Door[d]
Wood Doors[a,b]				
1-3/8	Panel door with 7/16-in. panels[e]	0.57	0.33	0.37
1-3/8	Hollow core flush door	0.47	0.30	0.32
1-3/8	Solid core flush door	0.39	0.26	0.28
1-3/4	Panel door with 7/16-in. panels[e]	0.54	0.32	0.36
1-3/4	Hollow core flush door	0.46	0.29	0.32
1-3/4	Panel door with 1-1/8-in. panels[e]	0.39	0.26	0.28
1-3/4	Solid core flush door	0.40	—	0.26
2-1/4	Solid core flush door	0.27	0.20	0.21
Steel Doors[b]				
1-3/4	Fiberglass or mineral wool core with steel stiffeners, no thermal break[f]	0.60	—	—
1-3/4	Paper honeycomb core without thermal break[f]	0.56	—	—
1-3/4	Solid urethane foam core without thermal break[a]	0.40	—	—
1-3/4	Solid fire rated mineral fiberboard core without thermal break[f]	0.38	—	—
1-3/4	Polystyrene core without thermal break (18 gage commercial steel)[f]	0.35	—	—
1-3/4	Polyurethane core without thermal break (18 gage commercial steel)[f]	0.29	—	—
1-3/4	Polyurethane core without thermal break (24 gage residential steel)[f]	0.29	—	—
1-3/4	Polyurethane core with thermal break and wood perimeter (24 gage residential steel)[f]	0.20	—	—
1-3/4	Solid urethane foam core with thermal break[a]	0.20	—	0.16

Note: All U-factors for exterior doors in this table are for doors with no glazing, except for the storm doors which are in addition to the main exterior door. Any glazing area in exterior doors should be included with the appropriate glass type and analyzed as a window (see Chapter 29). Interpolation and moderate extrapolation are permitted for door thicknesses other than those specified.
[a]Values are based on a nominal 32 in. by 80 in. door size with no glazing.
[b]Outside air conditions: 15 mph wind speed, 0°F air temperature; inside air conditions: natural convection, 70°F air temperature.
[c]Values for wood storm door are for approximately 50% glass area.
[d]Values for metal storm door are for any percent glass area.
[e]55% panel area.
[f]ASTM C 236 hotbox data on a nominal 3 ft by 7 ft door size with no glazing.



Use $z_f = -0.5$ for walls when total thickness of layer of materials attached to one side of metal frame ≤ **5/8 in. and** thermal resistivity of sheathing ≤ **1.5 h·ft²·°F/Btu·in.**



Use $z_f = +0.5$ for walls when total thickness of layer of materials attached to one side of metal frame ≤ **5/8 in. and** thermal resistivity of sheathing > **1.5 h·ft²·°F/Btu·in**

Find z_f in chart above for walls when total thickness of layer of materials attached to one side of metal frame > **5/8 in.**

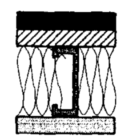


Fig. 7 Modified Zone Factor for Calculating R-Value of Metal Stud Walls with Cavity Insulation

Example 5. Calculate U_o for a wall 30 ft by 8 ft, constructed as in Example 1. The wall contains two double-glazed (0.5 in. airspace) fixed windows with wood/vinyl frames. (From Table 5 in Chapter 29, U = 0.52 Btu/h·ft²·°F.) One window is 60 in. by 34 in. and the second 36 in. by 30 in. The wall also contains a 1.75-in. solid core flush door with a metal storm door 34 in. by 80 in. (U = 0.26 Btu/h·ft²·°F from Table 6).

Solution. The U-factor for the wall was obtained in Example 1. The areas of the different components are:

$$A_{window} = [(60 \times 34) + (36 \times 30)]/144 = 21.7 \text{ ft}^2$$

$$A_{door} = (34 \times 80)/144 = 18.9 \text{ ft}^2$$

$$A_{wall} = (30 \times 8) - (21.7 + 18.9) = 199.4 \text{ ft}^2$$

Therefore, the combined thermal transmittance for the wall is:

$$U_o = \frac{(0.063 \times 199.4) + (0.52 \times 21.7) + (0.26 \times 18.9)}{(30 \times 8)}$$

$$= 0.119 \text{ Btu/h} \cdot \text{ft}^2 \cdot {}^\circ\text{F}$$

Slab-on-Grade and Below-Grade Construction

Heat transfer through basement walls and floors to the ground depends on the following factors: (1) the difference between the air temperature within the room and that of the ground and outside air, (2) the material of the walls or floor, and (3) the thermal conductivity of the surrounding earth. The latter varies with local conditions and is usually unknown. Because of the great thermal inertia of the surrounding soil, ground temperature varies with depth, and there is a substantial time lag between changes in outdoor air temperatures and corresponding changes in ground temperatures. As a result, ground-coupled heat transfer is less amenable to steady-state representation than above-grade building elements. However, several simplified procedures for estimating ground-coupled heat transfer have been developed. These fall into two principal categories: (1) those that reduce the ground heat transfer problem to a closed form solution, and (2) those that use simple regression equations developed from statistically reduced multidimensional transient analyses.

Closed form solutions, including the ASHRAE arc-length procedure discussed in Chapter 27 by Latta and Boileau (1969), generally reduce the problem to one-dimensional, steady-state heat transfer. These procedures use simple, "effective" U-factors or ground temperatures or both. Methods differ in the various parameters averaged or manipulated to obtain these effective values. Closed form solutions provide acceptable results in climates that have a single dominant season, because the dominant season persists long enough to permit a reasonable approximation of steady-state conditions at shallow depths. The large errors (percentage) that are likely during transition seasons should not seriously affect building design decisions, since these heat flows are relatively insignificant when compared with those of the principal season.

The ASHRAE arc-length procedure is a reliable method for wall heat losses in cold winter climates. Chapter 27 discusses a slab-on-grade floor model developed by one study. Although both procedures give results comparable to transient computer solutions for cold climates, their results for warmer U.S. climates differ substantially.

Research conducted by Hougten et al. (1942) and Dill et al. (1945) indicates a heat flow of approximately 2.0 Btu/h·ft² through an uninsulated concrete basement floor with a temperature difference of 20°F between the basement floor and the air 6 in. above it. A U-factor of 0.10 Btu/h·ft²·°F is sometimes used for concrete basement floors on the ground. For basement walls below grade, the temperature difference for winter design conditions is greater than for the floor. Test results indicate that at the midheight of the below-grade portion of the basement wall, the unit area heat loss is approximately twice that of the floor.

For concrete slab floors in contact with the ground at grade level, tests indicate that for small floor areas (equal to that of a 25 ft by 25 ft house) the heat loss can be calculated as proportional to the length of exposed edge rather than total area. This amounts to 0.81 Btu/h per linear foot of exposed edge per degree Fahrenheit difference between the indoor air temperature and the average outdoor air temperature. This value can be reduced appreciably by installing insulation under the ground slab and along the edge between the floor and abutting walls. In most calculations, if the perimeter loss is calculated accurately, no other floor losses need to be considered. Chapter 27 contains data for load calculations and heat loss values for below-grade walls and floors at different depths.

The second category of simplified procedures uses transient two-dimensional computer models to generate the ground heat transfer data that are then reduced to compact form by regression analysis (see Mitalas 1982 and 1983, Shipp 1983). These are the most accurate procedures available, but the database is very expensive to generate. In addition, these methods are limited to the range of climates and constructions specifically examined. Extrapolating beyond the outer bounds of the regression surfaces can produce significant errors.

Apparent Thermal Conductivity of Soil

Effective or apparent soil thermal conductivity is difficult to estimate precisely and may change substantially in the same soil at different times due to changed moisture conditions and the presence of

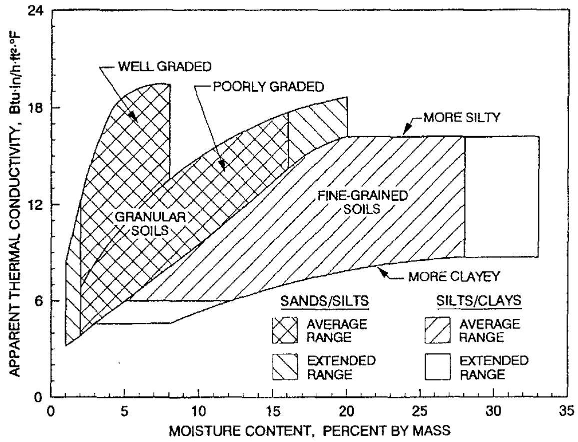


Fig. 8 Trends of Apparent Thermal Conductivity of Moist Soils

freezing temperatures in the soil. Figure 8 shows the typical apparent soil thermal conductivity as a function of moisture content for different general types of soil. The figure is based on data presented in Salomone and Marlowe (1989) using envelopes of thermal behavior coupled with field moisture content ranges for different soil types. In Figure 8, the term well-graded applies to granular soils with good representation of all particle sizes from largest to smallest. The term poorly graded refers to granular soils with either a uniform gradation, in which most particles are about the same size, or a skip (or gap) gradation, in which particles of one or more intermediate sizes are not present.

Although thermal conductivity varies greatly over the complete range of possible moisture contents for a soil, this range can be narrowed if it is assumed that the moisture contents of most field soils lie between the "wilting point" of the soil (i.e., the moisture content of a soil below which a plant cannot alleviate its wilting symptoms) and the "field capacity" of the soil (i.e., the moisture content of a soil that has been thoroughly wetted and then drained until the drainage rate has become negligibly small). After a prolonged dry spell, the moisture will be near the wilting point, and after a rainy period, the soil will have a moisture content near its field capacity. The moisture contents at these limits have been studied by many agricultural researchers, and data for different types of soil are given by Salomone and Marlowe (1989) and Kersten (1949). The shaded areas on Figure 8 approximate (1) the full range of moisture contents for different soil types and (2) a range between average values of each limit.

Table 7 gives a summary of design values for thermal conductivities of the basic soil classes. Table 8 gives ranges of thermal conductivity for some basic classes of rock. The value chosen depends on whether heat transfer is being calculated for minimum heat loss through the soil, as in a ground heat exchange system, or a maximum value, as in peak winter heat loss calculations for a basement. Hence, a high and a low value are given for each soil class.

As heat flows through the soil, the moisture tends to move away from the source of heat. This moisture migration provides initial mass transport of heat, but it also dries the soil adjacent to the heat source, hence lowering the apparent thermal conductivity in that zone of soil.

Trends typical in a soil when other factors are held constant are:

- *k* increases with moisture content
- *k* increases with increasing dry density of a soil
- *k* decreases with increasing organic content of a soil

Table 7 Typical Apparent Thermal Conductivity Values for Soils, Btu·in/h·ft²·°F

		Recommended Values for Design[a]	
	Normal Range	Low[b]	High[c]
Sands	4.2 to 17.4	5.4	15.6
Silts	6 to 17.4	11.4	15.6
Clays	6 to 11.4	7.8	10.8
Loams	6 to 17.4	6.6	15.6

[a]Reasonable values for use when no site- or soil-specific data are available.
[b]Moderately conservative values for minimum heat loss through soil (e.g., use in soil heat exchanger or earth-contact cooling calculations). Values are from Salomone and Marlowe (1989).
[c]Moderately conservative values for maximum heat loss through soil (e.g., use in peak winter heat loss calculations). Values are from Salomone and Marlowe (1989).

Table 8 Typical Apparent Thermal Conductivity Values for Rocks, Btu·in/h·ft²·°F

	Normal Range
Pumice, tuff, obsidian	3.6 to 15.6
Basalt	3.6 to 18.0
Shale	6 to 27.6
Granite	12 to 30
Limestone, dolomite, marble	8.4 to 30
Quartzose sandstone	9.6 to 54

- *k* tends to decrease for soils with uniform gradations and rounded soil grains (because the grain-to-grain contacts are reduced)
- *k* of a frozen soil may be higher or lower than that of the same unfrozen soil (because the conductivity of ice is higher than that of water but lower than that of the typical soil grains). Differences in *k* below moisture contents of 7 to 8% are quite small. At approximately 15% moisture content, differences in k-factors may vary up to 30% from unfrozen values.

When calculating annual energy use, values that represent typical site conditions as they vary during the year should be chosen. In climates where ground freezing is significant, accurate heat transfer simulations should include the effect of the latent heat of fusion of water. The energy released during this phase change significantly retards the progress of the frost front in moist soils.

Water Vapor Transmission Data for Building Components

Table 9 gives typical water vapor permeance and permeability values for common building materials. These values can be used to calculate water vapor flow through building components and assemblies using equations in Chapter 22.

MECHANICAL AND INDUSTRIAL SYSTEMS

Thermal Transmission Data

Table 10 lists the thermal conductivities of various materials used as industrial insulations. These values are functions of the arithmetic mean of the temperatures of the inner and outer surfaces for each insulation.

Heat Loss from Pipes and Flat Surfaces

Tables 11A, 11B, and 12 give heat losses from bare steel pipes and flat surfaces and bare copper tubes. These tables were calculated using ASTM *Standard* C 680. User inputs for the programs described in the standard include operating temperature, ambient temperature, pipe size, insulation type, number of insulation layers, and thickness for each layer. A program option allows the user to input a surface coefficient or surface emittance, surface orientation, and wind speed. The computer uses this information to calculate the

Table 9 Typical Water Vapor Permeance and Permeability Values for Common Building Materials[a]

Material	Thickness, in.	Permeance, Perm	Resistance[h], Rep	Permeability, Perm-in.	Resistance/in.[h], Rep/in.
Construction Materials					
Concrete (1:2:4 mix)				3.2	0.31
Brick masonry	4	0.8[f]	1.3		
Concrete block (cored, limestone aggregate)	8	2.4[f]	0.4		
Tile masonry, glazed	4	0.12[f]	8.3		
Asbestos cement board	0.12	4-8[d]	0.1-0.2		
With oil-base finishes		0.3-0.5[d]	2-3		
Plaster on metal lath	0.75	15[f]	0.067		
Plaster on wood lath		11[e]	0.091		
Plaster on plain gypsum lath (with studs)		20[f]	0.050		
Gypsum wall board (plain)	0.375	50[f]	0.020		
Gypsum sheathing (asphalt impregnated)	0.5			20[d]	0.050
Structural insulating board (sheathing quality)				20-50[f]	0.050-0.020
Structural insulating board (interior, uncoated)	0.5	50-90[f]	0.020-0.011		
Hardboard (standard)	0.125	11[f]	0.091		
Hardboard (tempered)	0.125	5[f]	0.2		
Built-up roofing (hot mopped)		0			
Wood, sugar pine				0.4-5.4[b]	2.5-0.19
Plywood (douglas fir, exterior glue)	0.25	0.7[f]	1.4		
Plywood (douglas fir, interior glue)	0.25	1.9[f]	0.53		
Acrylic, glass fiber reinforced sheet	0.056	0.12[d]	8.3		
Polyester, glass fiber reinforced sheet	0.048	0.05[d]	20		
Thermal Insulations					
Air (still)				120[f]	0.0083
Cellular glass				0[d]	∞
Corkboard				2.1-2.6[d]	0.48-0.38
				9.5[e]	0.11
Mineral wool (unprotected)				116[e]	0.0086
Expanded polyurethane (R-11 blown) board stock				0.4-1.6[d]	2.5-0.62
Expanded polystyrene—extruded				1.2[d]	0.83
Expanded polystyrene—bead				2.0-5.8[d]	0.50-0.17
Phenolic foam (covering removed)				26	0.038
Unicellular synthetic flexible rubber foam				0.02-0.15[d]	50-6.7
Plastic and Metal Foils and Films[c]					
Aluminum foil	0.001	0.0[d]	∞		
Aluminum foil	0.00035	0.05[d]	20		
Polyethylene	0.002	0.16[d]	6.3		3100
Polyethylene	0.004	0.08[d]	12.5		3100
Polyethylene	0.006	0.06[d]	17		3100
Polyethylene	0.008	0.04[d]	25		3100
Polyethylene	0.010	0.03[d]	33		3100
Polyvinylchloride, unplasticized	0.002	0.68[d]	1.5		
Polyvinylchloride, plasticized	0.004	0.8-1.4[d]	1.3-0.72		
Polyester	0.001	0.73[d]	1.4		
Polyester	0.0032	0.23[d]	4.3		
Polyester	0.0076	0.08[d]	12.5		
Cellulose acetate	0.01	4.6[d]	0.2		
Cellulose acetate	0.125	0.32[d]	3.1		

heat flow and the surface temperature. The programs calculate the surface coefficients if the user has not already supplied them.

The equations used in ASTM C 680 are:

$$h_{cv} = C\left(\frac{1}{d}\right)^{0.2}\left(\frac{1}{T_{avg}}\right)^{0.181}(\Delta T^{0.266})\sqrt{1 + 1.277(\text{Wind})} \qquad (6)$$

where

h_{cv} = convection surface coefficient, Btu/h·ft²·°F
d = diameter for cylinder, in. For flat surfaces and large cylinders (d > 24 in.), use d = 24 in.
T_{avg} = average temperature of air film = $(T_a + T_s)/2$, °R
T_a = temperature of ambient air, °R
T_s = temperature of surface, °R
ΔT = surface to air temperature difference, °R
Wind = air speed, mph
C = constant depending on shape and heat flow condition
= 1.016 for horizontal cylinders
= 1.235 for longer vertical cylinders
= 1.394 for vertical plates
= 1.79 for horizontal plates, warmer than air, facing upward
= 0.89 for horizontal plates, warmer than air, facing downward
= 0.89 for horizontal plates, cooler than air, facing upward
= 1.79 for horizontal plates, cooler than air, facing downward

Table 9 Typical Water Vapor Permeance and Permeability Values for Common Building Materials (*Concluded*)[a]

Material	Weight, lb/100 ft²	Permeance, Perms Dry-Cup	Permeance, Perms Wet-Cup	Permeance, Perms Other	Resistance[h] Rep Dry-Cup	Resistance[h] Rep Wet-Cup	Resistance[h] Rep Other
Building Paper, Felts, Roofing Papers[g]							
Duplex sheet, asphalt laminated, aluminum foil one side	8.6	0.002	0.176		500	5.8	
Saturated and coated roll roofing	65	0.05	0.24		20	4.2	
Kraft paper and asphalt laminated, reinforced 30-120-30	6.8	0.3	1.8		3.3	0.55	
Blanket thermal insulation backup paper, asphalt coated	6.2	0.4	0.6-4.2		2.5	1.7-0.24	
Asphalt-saturated and coated vapor retarder paper	8.6	0.2-0.3	0.6		5.0-3.3	1.7	
Asphalt-saturated, but not coated, sheathing paper	4.4	3.3	20.2		0.3	0.05	
15-lb asphalt felt	14	1.0	5.6		1.0	0.18	
15-lb tar felt	14	4.0	18.2		0.25	0.055	
Single-kraft, double	3.2	31	42		0.032	0.024	
Liquid-Applied Coating Materials	**Thickness, in.**						
Commercial latex paints (dry film thickness)[i]							
Vapor retarder paint	0.0031			0.45			2.22
Primer-sealer	0.0012			6.28			0.16
Vinyl acetate/acrylic primer	0.002			7.42			0.13
Vinyl-acrylic primer	0.0016			8.62			0.12
Semi-gloss vinyl-acrylic enamel	0.0024			6.61			0.15
Exterior acrylic house and trim	0.0017			5.47			0.18
Paint-2 coats							
Asphalt paint on plywood			0.4			2.5	
Aluminum varnish on wood		0.3-0.5			3.3-2.0		
Enamels on smooth plaster				0.5-1.5			2.0-0.66
Primers and sealers on interior insulation board				0.9-2.1			1.1-0.48
Various primers plus 1 coat flat oil paint on plaster				1.6-3.0			0.63-0.33
Flat paint on interior insulation board				4			0.25
Water emulsion on interior insulation board				30-85			0.03-0.012
	Weight, oz/ft²						
Paint-3 coats							
Exterior paint, white lead and oil on wood siding		0.3-1.0			3.3-1.0		
Exterior paint, white lead-zinc oxide and oil on wood		0.9			1.1		
Styrene-butadiene latex coating	2	11			0.09		
Polyvinyl acetate latex coating	4	5.5			0.18		
Chlorosulfonated polyethylene mastic	3.5	1.7			0.59		
	7.0	0.06			16		
Asphalt cutback mastic, 1/16 in., dry		0.14			7.2		
3/16 in., dry		0.0			—		
Hot melt asphalt	2	0.5			2		
	3.5	0.1			10		

[a]This table permits comparisons of materials; but in the selection of vapor retarder materials, exact values for permeance or permeability should be obtained from the manufacturer or from laboratory tests. The values shown indicate variations among mean values for materials that are similar but of different density, orientation, lot, or source. The values should not be used as design or specification data. Values from dry-cup and wet-cup methods were usually obtained from investigations using ASTM E 96 and C 355; values shown under others were obtained by two-temperature, special cell, and air velocity methods. Permeance, resistance, permeability, and resistance per unit thickness values are given in the following units:

Permeance	Perm	= gr/h·ft²·in. Hg
Resistance	Rep	= in. Hg·ft²·h/gr
Permeability	Perm-in.	= gr/h·ft²·(in. Hg/in.)
Resistance/unit thickness	Rep/in.	= (in. Hg·ft²·h/gr)/in.

[b]Depending on construction and direction of vapor flow.
[c]Usually installed as vapor retarders, although sometimes used as an exterior finish and elsewhere near the cold side, where special considerations are then required for warm side barrier effectiveness.
[d]Dry-cup method.
[e]Wet-cup method.
[f]Other than dry- or wet-cup method.
[g]Low permeance sheets used as vapor retarders. High permeance used elsewhere in construction.
[h]Resistance and resistance/in. values have been calculated as the reciprocal of the permeance and permeability values.
[i]Cast at 10 mils (0.01 in.) wet film thickness.

$$h_{rad} = \frac{\varepsilon\sigma(T_a^4 - T_s^4)}{T_a - T_s} \quad (7)$$

where

h_{rad} = radiation surface coefficient, Btu/h·ft²·°F
ε = surface emittance
σ = Stefan-Boltzmann constant = 0.1713×10^{-8} Btu/h·ft²·°R⁴

Example 6. Compute the total annual heat loss from 165 ft of nominal 2-in. bare steel pipe in service 4000 h per year. The pipe is carrying steam at 10 psig and is exposed to an average air temperature of 80°F.

Solution. The pipe temperature is taken as the steam temperature, which is 239.4°F, obtained by interpolation from Steam Tables. By interpolation in Table 11A between 180°F and 280°F, heat loss from a nominal 2-in. pipe is 285 Btu/h·ft. Total annual heat loss from the entire line is 285 Btu/h·ft × 165 ft × 4000 h = 188×10^6 Btu.

In calculating heat flow, Equations (9) and (10) from Chapter 22 generally are used. For dimensions of standard pipe and fitting sizes, refer to the *Piping Handbook*. For insulation product dimensions, refer to ASTM *Standard* C 585, or to the insulation manufacturers' literature.

Examples 7 and 8 illustrate how Equations (9) and (10) from Chapter 22 can be used to determine heat loss from both flat and

Table 10 Typical Thermal Conductivity for Industrial Insulations at Various Mean Temperatures—Design Values[a]

Material	Max. Temp.,[b] °F	Typical Density, lb/ft³	Typical Conductivity in Btu·in/h·ft²·°F at Mean Temp., °F													
			−100	−75	−50	−25	0	25	50	75	100	200	300	500	700	900
BLANKETS AND FELTS																
ALUMINOSILICATE FIBER																
7 to 10 μm diameter fiber	1800	4								0.24		0.32		0.54	0.99	1.03
	2000	6-8								0.25		0.30		0.48	0.78	0.95
3 μm diameter fiber	2200	4								0.22		0.29		0.45	0.59	0.74
MINERAL FIBER (Rock, slag, or glass)																
Blanket, metal reinforced	1200	6-12									0.26	0.32	0.39	0.54		
	1000	2.5-6									0.24	0.31	0.40	0.61		
Blanket, flexible, fine-fiber organic bonded	350	0.75				0.25	0.26	0.28	0.30	0.33	0.36	0.53				
		0.75				0.24	0.25	0.27	0.29	0.32	0.34	0.48				
		1.0				0.23	0.24	0.25	0.27	0.29	0.32	0.43				
		1.5				0.21	0.22	0.23	0.25	0.27	0.28	0.37				
		2.0				0.20	0.21	0.22	0.23	0.25	0.26	0.33				
		3.0				0.19	0.20	0.21	0.22	0.23	0.24	0.31				
Blanket, flexible, textile fiber, organic bonded	350	0.65				0.27	0.28	0.29	0.30	0.31	0.32	0.50	0.68			
		0.75				0.26	0.27	0.28	0.29	0.31	0.32	0.48	0.66			
		1.0				0.24	0.25	0.26	0.27	0.29	0.31	0.45	0.60			
		1.5				0.22	0.23	0.24	0.25	0.27	0.29	0.39	0.51			
		3.0				0.20	0.21	0.22	0.23	0.24	0.25	0.32	0.41			
Felt, semirigid organic bonded	400	3-8						0.24	0.25	0.26	0.27	0.35	0.44			
Laminated and felted without binder	850	3	0.16	0.17	0.18	0.19	0.20	0.21	0.22	0.23	0.24	0.35	0.55			
	1200	7.5											0.35	0.45	0.60	
BLOCKS, BOARDS, AND PIPE INSULATION																
MAGNESIA	600	11-12									0.35	0.38	0.42			
85% CALCIUM SILICATE	1200	11-15									0.38	0.41	0.44	0.52	0.62	0.72
	1800	12-15												0.63	0.74	0.95
CELLULAR GLASS	900	7.8-8.2	0.24	0.25	0.26	0.28	0.29	0.30	0.32	0.33	0.34	0.41	0.49	0.70	1.01	
DIATOMACEOUS SILICA	1600	21-22												0.64	0.68	0.72
	1900	23-25												0.70	0.75	0.80
MINERAL FIBER (Glass)																
Organic bonded, block and boards	400	3-10	0.16	0.17	0.18	0.19	0.20	0.22	0.24	0.25	0.26	0.33	0.40			
Nonpunking binder	1000	3-10									0.26	0.31	0.38	0.52		
Pipe insulation, slag, or glass	350	3-4					0.20	0.21	0.22	0.23	0.24	0.29				
	500	3-10					0.20	0.22	0.24	0.25	0.26	0.33	0.40			
Inorganic bonded block	1000	10-15									0.33	0.38	0.45	0.55		
	1800	15-24									0.32	0.37	0.42	0.52	0.62	0.74
Pipe insulation, slag, or glass	1000	10-15									0.33	0.38	0.45	0.55		
Resin binder		15	0.23	0.24	0.25	0.26	0.28	0.29								
RIGID POLYSTYRENE																
Extruded (CFC-12 exp.)(smooth skin surface)	165	1.8-3.5	0.16	0.16	0.17	0.16	0.17	0.18	0.19	0.20						
Molded beads	165	1	0.17	0.19	0.20	0.21	0.22	0.24	0.25	0.26	0.28					
		1.25	0.17	0.18	0.19	0.20	0.22	0.23	0.24	0.25	0.27					
		1.5	0.16	0.17	0.19	0.20	0.21	0.22	0.23	0.24	0.26					
		1.75	0.16	0.17	0.18	0.19	0.20	0.22	0.23	0.24	0.25					
		2.0	0.15	0.16	0.18	0.19	0.20	0.21	0.22	0.23	0.24					
RIGID POLYURETHANE/POLYISOCYANURATE[c,d]																
Unfaced (CFC-11 exp.)	210	1.5-2.5	0.16	0.17	0.18	0.18	0.18	0.17	0.16	0.16	0.17					
RIGID POLYISOCYANURATE																
Gas-impermeable facers (CFC-11 exp.)	250	2.0						0.12	0.13	0.14	0.15					
RIGID PHENOLIC																
Closed cell (CFC-11, CFC-113 exp.)		3.0						0.11	0.115	0.12	0.125					
RUBBER, Rigid foamed	150	4.5						0.20	0.21	0.22	0.23					
VEGETABLE AND ANIMAL FIBER																
Wool felt (pipe insulation)	180	20						0.28	0.30	0.31	0.33					
INSULATING CEMENTS																
MINERAL FIBER (Rock, slag, or glass)																
With colloidal clay binder	1800	24-30									0.49	0.55	0.61	0.73	0.85	
With hydraulic setting binder	1200	30-40									0.75	0.80	0.85	0.95		
LOOSE FILL																
Cellulose insulation (milled pulverized paper or wood pulp)		2.5-3							0.26	0.27	0.29					
Mineral fiber, slag, rock, or glass		2-5			0.19	0.21	0.23	0.25	0.26	0.28	0.31					
Perlite (expanded)		3-5	0.22	0.24	0.25	0.27	0.28	0.30	0.31	0.33	0.35					
Silica aerogel		7.6			0.13	0.14	0.15	0.15	0.16	0.17	0.18					
Vermiculite (expanded)		7-8.2			0.39	0.40	0.42	0.44	0.45	0.47	0.49					
		4-6			0.34	0.35	0.38	0.40	0.42	0.44	0.46					

[a]Representative values for dry materials, which are intended as design (not specification) values for materials in normal use. Insulation materials in actual service may have thermal values that vary from design values depending on their in-situ properties (e.g., density and moisture content). For properties of a particular product, use the value supplied by the manufacturer or by unbiased tests.

[b]These temperatures are generally accepted as maximum. When operating temperature approaches these limits, follow the manufacturers' recommendations.

[c]Some polyurethane foams are formed by means that produce a stable product (with respect to k), but most are blown with refrigerant and will change with time.

[d]See Table 4, footnote i.

[e]See Table 4, footnote j.

Table 11A Heat Loss from Bare Steel Pipe to Still Air at 80°F[a], Btu/h·ft

Nominal Pipe Size[b], in.	Pipe Inside Temperature, °F									
	180	280	380	480	580	680	780	880	980	1080
0.50	59.3	147.2	263.2	412.3	600.9	836.8	1128.6	1485.6	1918.0	2436.8
0.75	72.5	180.1	322.6	506.2	739.2	1031.2	1392.9	1836.0	2373.5	3018.8
1.00	88.8	220.8	396.1	622.7	910.9	1272.6	1721.2	2271.5	2939.4	3741.6
1.25	109.7	272.8	490.4	772.3	1131.7	1583.8	2145.6	2835.4	3673.4	4680.9
1.50	123.9	308.5	555.1	875.1	1283.8	1798.3	2438.2	3224.6	4180.5	5330.0
2.00	151.8	378.1	681.4	1076.3	1581.5	2218.9	3012.6	3989.2	5177.2	6606.8
2.50	180.5	450.0	811.9	1284.0	1888.8	2652.6	3604.3	4775.3	6199.5	7912.5
3.00	215.9	538.8	973.5	1541.8	2271.4	3194.0	4344.9	5762.2	7486.9	9562.3
3.50	243.9	609.0	1101.4	1746.1	2574.7	3623.6	4933.0	6546.4	8510.4	10874.3
4.00	271.6	678.6	1228.2	1948.7	2875.9	4050.5	5517.5	7326.0	9528.1	12178.9
4.50	299.2	747.7	1354.4	2150.9	3176.8	4477.7	6103.8	8109.5	10553.2	13496.2
5.00	329.8	824.7	1494.8	2375.4	3510.6	4950.7	6751.3	8972.5	11678.4	14936.3
6.00	387.1	968.7	1757.8	2796.8	4138.0	5841.4	7972.7	10603.1	13808.2	17667.6
7.00	440.5	1102.8	2003.0	3189.9	4723.9	6673.5	9114.2	12127.4	15799.4	20220.8
8.00	493.3	1235.7	2246.1	3580.0	5305.5	7500.0	10248.4	13642.2	17778.2	22758.0
9.00	545.9	1368.1	2488.8	3970.2	5888.7	8331.0	11392.1	15174.5	19787.1	25343.6
10.00	604.3	1514.8	2757.2	4400.7	6530.1	9241.1	12638.6	16835.1	21949.2	28104.9
11.00	656.0	1644.8	2995.5	4783.8	7102.1	10054.9	13756.2	18328.4	23900.3	30606.1
12.00	704.0	1762.3	3203.8	5104.9	7557.3	10661.8	14524.9	19256.7	24967.6	31766.8
14.00	771.0	1934.2	3525.9	5636.0	8373.9	11862.4	16235.5	21635.6	28212.3	36120.3
16.00	872.2	2189.0	3993.2	6387.4	9495.9	13458.0	18424.8	24556.6	32021.1	40990.7
18.00	972.5	2441.7	4456.7	7132.9	10609.4	15041.3	20596.7	27453.2	35795.6	45813.1
20.00	1072.1	2692.4	4916.8	7873.2	11715.1	16613.4	22752.5	30326.8	39537.6	50590.0
24.00	1269.3	3188.9	5828.3	9339.9	13905.5	19726.9	27019.7	36010.1	46930.3	60014.7

Table 11B Heat Loss from Flat Surfaces to Still Air at 80°F, Btu/h·ft²

	Surface Inside Temperature, °F									
	180	280	380	480	580	680	780	880	980	1080
Vertical surface	212.2	533.1	973.3	1558.6	2321.2	3298.0	4530.1	6062.8	7945.5	10231.5
Horizontal surface										
Facing up	234.7	586.4	1061.1	1683.5	2484.9	3501.9	4775.4	6350.4	8276.3	10606.1
Facing down	183.6	465.3	861.4	1399.6	2112.8	3038.4	4217.8	5696.7	7524.5	9754.7

[a]Calculations from ASTM C 680; steel: $k = 314.4$ Btu·in/h·ft²·°F; $\varepsilon = 0.94$.

[b]Losses per square foot of pipe for pipes larger than 24 in. can be considered the same as losses per square foot for 24-in. pipe.

cylindrical surfaces. Figure 9 shows surface resistance as a function of heat transmission for both flat and cylindrical surfaces. The surface emittance is assumed to be 0.85 to 0.90 in still air at 80°F.

Example 7. Compute the heat loss from a boiler wall if the interior insulation surface temperature is 1100°F and ambient still air temperature is 80°F. The wall is insulated with 4.5 in. of mineral fiber block and 0.5 in. of mineral fiber insulating and finishing cement.

Solution. Assume that the mean temperature of the mineral fiber block is 700°F, the mean temperature of the insulating cement is 200°F, and the surface resistance R_s is 0.60 ft²·°F·h/Btu.

From Table 10, $k_1 = 0.62$ and $k_2 = 0.80$. Using Equation (9) from Chapter 22:

$$q_s = \frac{1100 - 80}{(4.5/0.62) + (0.5/0.80) + 0.60} = 120.2 \text{ Btu/h} \cdot \text{ft}^2$$

As a check, from Figure 9, at 120.2 Btu/h·ft², $R_s = 0.56$. The mean temperature of the mineral fiber block is:

$$4.5/0.62 = 7.26;\ 7.26/2 = 3.63$$

$$1100 - \frac{3.63}{8.48}(1020) = 663°\text{F}$$

and the mean temperature of the insulating cement is:

$$0.5/0.80 = 0.63;\ 0.63/2 = 0.31;\ 7.26 + 0.31 = 7.57$$

$$1100 - \frac{7.57}{8.48}(1020) = 189°\text{F}$$

From Table 10, at 663°F, $k_1 = 0.60$; at 189°F, $k_2 = 0.79$.

Using these adjusted values to recalculate q_s:

$$q_s = \frac{1020}{(4.5/0.60) + (0.5/0.79) + 0.56} = \frac{1020}{8.69}$$

$$= 117.4 \text{ Btu/h} \cdot \text{ft}^2$$

From Figure 9, at 117.4 Btu/h·ft², $R_s = 0.56$. The mean temperature of the mineral fiber block is:

$$4.5/0.6 = 7.50;\ 7.50/2 = 3.75$$

$$1100 - \frac{3.75}{8.69}(1020) = 660°\text{F}$$

and the mean temperature of the insulating cement is:

$$0.5/0.79 = 0.63;\ 0.63/2 = 0.31;\ 7.50 + 0.31 = 7.81$$

$$1100 - \frac{7.81}{8.69}(1020) = 183°\text{F}$$

From Table 10, at 660°F, $k_1 = 0.60$; at 183°F, $k_2 = 0.79$.

Since R_s, k_1, and k_2 do not change at these values, $q_s = 117.4$ Btu/h·ft.

Example 8. Compute heat loss per square foot of outer surface of insulation if pipe temperature is 1200°F and ambient still air temperature is 80°F. The pipe is nominal 6-in. steel pipe, insulated with a nominal 3-in. thick diatomaceous silica as the inner layer and a nominal 2-in. thick calcium silicate as the outer layer.

Table 12 Heat Loss from Bare Copper Tube to Still Air at 80°F[a], Btu/h·ft

Nominal Tube Size, in.	Tube Inside Temperature, °F								
	120	150	180	210	240	270	300	330	
0.250	7.1	14.1	21.9	30.6	39.9	49.9	60.6	71.9	
0.375	9.1	18.0	28.1	39.1	51.1	63.9	77.6	92.2	
0.500	11.0	21.8	34.0	47.4	61.9	77.5	94.1	111.8	
0.750	14.7	29.1	45.4	63.3	82.7	103.6	126.0	149.8	
1.000	18.3	36.2	56.4	78.7	102.8	128.9	156.7	186.5	
1.250	21.8	43.1	67.2	93.6	122.4	153.4	186.7	222.2	
1.500	25.2	49.8	77.6	108.3	141.5	177.4	216.0	257.1	
2.000	31.8	62.9	98.0	136.7	178.8	224.3	273.1	325.4	
2.500	38.3	75.6	117.9	164.4	215.1	269.8	328.7	391.8	Dull ε = 0.44
3.000	44.6	88.1	137.2	191.5	250.5	314.4	383.2	456.9	
3.500	50.8	100.3	156.3	218.0	285.4	358.2	436.7	520.8	
4.000	57.0	112.3	175.0	244.2	319.7	401.4	489.4	583.9	
5.000	69.0	135.9	211.7	295.5	386.9	486.0	592.8	707.6	
6.000	80.7	159.0	247.7	345.7	452.8	568.9	694.2	829.0	
8.000	103.7	204.1	317.8	443.7	581.3	730.7	892.1	1066.0	
10.000	126.1	247.9	386.1	539.1	706.5	888.4	1085.2	1297.4	
12.000	148.0	290.9	453.0	632.5	829.2	1043.1	1274.6	1524.4	
0.250	5.4	10.8	16.9	23.5	30.5	37.9	45.5	53.5	
0.375	6.8	13.7	21.4	29.7	38.6	47.9	57.6	67.6	
0.500	8.2	16.4	25.7	35.7	46.3	57.4	69.1	81.2	
0.750	10.7	21.6	33.8	46.9	60.9	75.6	90.9	106.8	
1.000	13.2	26.5	41.4	57.6	74.7	92.8	111.6	131.2	
1.250	15.5	31.3	48.8	67.8	88.0	109.3	131.6	154.7	
1.500	17.8	35.8	56.0	77.8	100.9	125.3	150.8	177.4	
2.000	22.2	44.6	69.7	96.8	125.7	156.1	187.9	221.1	Bright ε = 0.08
2.500	26.4	53.0	82.8	115.1	149.5	185.6	223.5	263.0	
3.000	30.5	61.2	95.6	132.8	172.4	214.2	257.9	303.5	
3.500	34.4	69.1	107.9	150.0	194.8	242.0	291.4	342.9	
4.000	38.3	76.8	120.0	166.8	216.6	269.1	324.1	381.4	
5.000	45.7	91.8	143.4	199.3	258.8	321.6	387.4	456.1	
6.000	53.0	106.3	166.0	230.7	299.7	372.5	448.7	528.3	
8.000	66.8	134.1	209.4	291.1	378.2	470.1	566.5	667.2	
10.000	80.2	160.8	251.0	349.0	453.4	563.7	679.5	800.4	
12.000	93.0	186.5	291.3	404.9	526.1	654.2	788.7	929.3	

[a]Calculations from ASTM C 680; for copper: $k = 2784$ Btu·in/h·ft²·°F.

Solution. From Chapter 40 of the 1996 *ASHRAE Handbook—Equipment*, $r_o = 3.31$ in. A nominal 3-in. thick diatomaceous silica insulation to fit a nominal 6-in. steel pipe is 3.02 in. thick. A nominal 2-in. thick calcium silicate insulation to fit over the 3.02-in. diatomaceous silica is 2.08 in. thick. Therefore, $r_i = 6.33$ in. and $r_s = 8.41$ in..

Assume that the mean temperature of the diatomaceous silica is 600°F, the mean temperature of the calcium silicate is 250°F and the surface resistance R_s is 0.50. From Table 10, $k_1 = 0.66$; $k_2 = 0.42$. By Equation (10) from Chapter 22:

$$q_s = \frac{1200 - 80}{[8.41\ln(6.33/3.31)/0.66] + [8.41\ln(8.41/3.31)/0.40] + 0.50}$$

$$= \frac{1120}{(5.45/0.66) + (2.39/0.40) + 0.50} = 76.0 \text{ Btu/h} \cdot \text{ft}^2$$

From Figure 9, at 76.0 Btu/h·ft², $R_s = 0.60$. The mean temperature of the diatomaceous silica is:

$$5.45/0.66 = 8.26;\ 8.26/2 = 4.13$$

$$1200 - \frac{4.13}{14.83}(1120) = 888°\text{F}$$

and the mean temperature of the calcium silicate is:

$$2.39/0.40 = 5.98;\ 5.98/2 = 2.99;\ 8.26 + 2.99 = 11.25$$

$$1200 - \frac{11.25}{14.83}(1120) = 350°\text{F}$$

From Table 10, $k_1 = 0.72$; $k_2 = 0.46$. Recalculating:

$$q_s = \frac{1120}{(5.45/0.72) + (2.39/0.46) + 0.60} = 83.8 \text{ Btu/h} \cdot \text{ft}^2$$

From Figure 9 at 83.8 Btu/h·ft², $R_s = 0.59$. The mean temperature of the diatomaceous silica is:

$$5.45/0.72 = 7.57;\ 7.57/2 = 3.78$$

$$1200 - \frac{3.78}{13.36}(1120) = 883°\text{F}$$

and the mean temperature of the calcium silicate is:

$$2.39/0.40 = 5.98;\ 5.98/2 = 2.99;\ 8.26 + 2.99 = 11.25$$

$$1200 - \frac{11.25}{14.83}(1120) = 350°\text{F}$$

From Table 10, $k_1 = 0.72$; $k_2 = 0.46$. Recalculating:

$$2.39/0.46 = 5.20;\ 5.20/2 = 2.60;\ 7.57 + 2.60 = 10.17$$

$$1200 - \frac{10.17}{13.36}(1120) = 347°\text{F}$$

Since R_s, k_1, and k_2 do not change at 83.8 Btu/h·ft², this is q_s. The heat flow per ft² of the inner surface of the insulation is:

$$q_o = q_s(r_s/r_o) = 83.8(8.41/3.31) = 213 \text{ Btu/h} \cdot \text{ft}^2$$

Table 13 Recommended Thicknesses for Pipe and Equipment Insulation

Nom Dia., in.		MINERAL FIBER (Fiberglass and Rock Wool)										CALCIUM		
		Process Temperature, °F										Process Temp., °F		
		150	250	350	450	550	650	750	850	950	1050	150	250	350
	Thickness	1	1½	2	2½	3	3½	4	4	4½	5½	1	1½	2
½	Heat loss	8	16	24	33	43	54	66	84	100	114	13	24	34
	Surface temp.	72	75	76	78	79	81	82	86	87	87	75	78	80
	Thickness	1	1½	2	2½	3½	4	4	4½	5	5½	1	2	2½
1	Heat loss	11	21	30	41	49	61	79	96	114	135	16	26	38
	Surface temp.	73	76	78	80	79	81	84	86	88	89	76	76	79
	Thickness	1	2	2½	3	4	4	4	5½	5½	6	1½	2½	3
1½	Heat loss	14	22	33	45	54	73	94	103	128	152	17	29	42
	Surface temp.	73	74	77	79	79	82	86	84	88	90	73	75	78
	Thickness	1½	2	3	3½	4	4	4	5½	6	6	1½	2½	3
2	Heat loss	13	25	34	47	61	81	105	114	137	168	19	32	47
	Surface temp.	71	75	75	77	79	83	87	85	87	91	74	76	79
	Thickness	1½	2½	3½	4	4	4½	4½	6	6½	7	2	3	3½
3	Heat loss	16	28	39	54	75	94	122	133	154	184	21	37	54
	Surface temp.	72	74	75	77	81	83	87	86	87	90	73	75	78
	Thickness	1½	3	4	4	4	5	5½	6	7	7½	2	3	4
4	Heat loss	19	29	42	63	88	102	126	152	174	206	25	43	58
	Surface temp.	72	73	74	78	82	86	85	87	88	90	70	76	77
	Thickness	2	3	4	4	4½	5	5½	6½	7½	8	2	3½	4
6	Heat loss	21	38	54	81	104	130	159	181	208	246	33	51	75
	Surface temp.	71	74	75	79	82	84	87	88	89	91	74	75	79
	Thickness	2	3½	4	4	5	5	5½	7	8	8½	2½	3½	4
8	Heat loss	26	42	65	97	116	155	189	204	234	277	35	62	90
	Surface temp.	71	73	76	80	81	86	89	88	89	92	73	76	79
	Thickness	2	3½	4	4	5	5½	5½	7½	8½	9	2½	4	4
10	Heat loss	32	50	77	115	136	170	220	226	259	307	41	66	106
	Surface temp.	72	74	77	81	82	85	90	87	89	91	73	75	80
	Thickness	2	3½	4	4	5	5½	5½	7½	8½	9½	2½	4	4
12	Heat loss	36	57	87	131	154	192	249	253	290	331	47	75	121
	Surface temp.	72	74	77	82	82	86	91	88	89	91	73	76	81
	Thickness	2	3½	4	4	5	5½	6½	7½	9	9½	2½	4	4
14	Heat loss	40	61	94	141	165	206	236	271	297	352	51	81	130
	Surface temp.	72	74	77	82	83	86	87	89	89	91	73	76	81
	Thickness	2½	3½	4	4	5½	5½	7	8	9	10	3	4	4
16	Heat loss	37	68	105	157	171	228	247	284	326	372	50	90	144
	Surface temp.	71	74	78	83	82	87	86	88	89	91	72	76	82
	Thickness	2½	3½	4	4	5½	5½	7	8	9	10	3	4	4
18	Heat loss	41	75	115	173	187	250	270	310	354	404	55	99	159
	Surface temp.	71	74	78	83	83	87	87	88	90	91	73	76	82
	Thickness	2½	3½	4	4	5½	5½	7	8	9	10	3	4	4
20	Heat loss	45	82	126	189	204	272	292	335	383	436	60	108	174
	Surface temp.	71	75	78	83	83	87	87	89	90	92	73	77	82
	Thickness	2½	4	4	4	5½	6	7½	8	9	10	3	4	4
24	Heat loss	53	86	147	221	237	295	320	386	439	498	71	127	203
	Surface temp.	71	74	78	83	83	86	86	89	91	93	73	77	82
	Thickness	2½	4	4	4	5½	6½	7½	8½	10	10	3	4	4
30	Heat loss	65	105	179	268	286	332	383	439	481	591	86	154	247
	Surface temp.	71	74	79	84	84	85	87	89	89	94	73	77	83
	Thickness	2½	4	4	4	5½	7	8	9	10	10	2½	4	4
36	Heat loss	77	123	211	316	335	364	422	486	556	683	119	181	291
	Surface temp.	71	74	79	84	84	84	86	88	90	94	74	77	83
	Thickness	2	3½	4	4½	5½	8½	9½	10	10	10	2½	3½	4
Flat	Heat loss	10	14	20	27	31	27	31	38	47	58	12	20	28
	Surface temp.	72	74	77	80	82	80	82	85	89	93	73	77	81

Consult manufacturer's literature for product temperature limitations. Table is based on typical operating conditions, e.g., 65°F ambient temperature and 7.5 mph wind speed, and may not represent actual conditions of use. Units for thickness, heat loss, and surface temperature are in inches, Btu/h·ft (Btu/h·ft^2 for flat surfaces), and °F, respectively.

Table 13 Recommended Thicknesses for Pipe and Equipment Insulation (*Concluded*)

Nom. Dia., in.		SILICATE							CELLULAR GLASS						
		Process Temperature, °F							Process Temperature, °F						
		450	550	650	750	850	950	1050	150	250	350	450	550	650	750
½	Thickness	2½	3	3½	4	4	4	4	1½	1½	2	2½	3	3½	4
	Heat loss	42	53	63	75	90	108	128	9	23	34	48	62	78	92
	Surface temp.	81	82	83	84	87	91	94	70	76	78	82	83	85	84
1	Thickness	3	3½	4	4	4	4	4	1½	2	2½	3	3½	4	4
	Heat loss	49	60	72	89	109	130	154	12	25	38	52	68	86	112
	Surface temp.	80	82	83	86	90	94	98	71	75	77	79	81	83	88
1½	Thickness	3½	4	4	4	4	5	5	1½	2½	3	4	4	4	4
	Heat loss	54	68	86	106	128	139	164	15	28	44	56	79	105	137
	Surface temp.	80	81	85	88	92	91	94	72	75	77	78	82	87	92
2	Thickness	3½	4	4½	5	5½	6	6	1½	2½	3	4	4	4	4½
	Heat loss	61	75	90	106	123	142	167	17	31	47	61	84	113	140
	Surface temp.	81	82	84	85	87	88	91	72	74	77	78	82	86	89
3	Thickness	4	4½	5	5½	6	6	6	1½	3	3½	4	4	4½	5
	Heat loss	71	87	105	123	143	71	202	22	35	54	75	105	132	161
	Surface temp.	80	82	84	85	87	90	94	73	74	77	79	84	86	89
4	Thickness	4	4½	5	5½	6	6½	7	2	3	4	4	4	4½	5
	Heat loss	82	101	121	142	164	187	213	22	41	59	87	122	150	185
	Surface temp.	81	83	85	87	89	90	92	71	74	76	80	85	87	90
6	Thickness	4	4½	5	5½	6	7	8	2	3½	4	4	4½	5½	6
	Heat loss	105	129	153	178	205	224	245	30	48	74	111	144	171	212
	Surface temp.	83	85	87	89	91	91	91	72	74	77	82	85	86	89
8	Thickness	4½	5	5	6	7	8	8½	2½	3½	4	4	5	5½	6½
	Heat loss	117	144	183	200	220	243	277	30	58	90	134	161	203	238
	Surface temp.	82	85	89	89	89	90	92	71	74	78	83	84	87	89
10	Thickness	4	5	5½	6	7½	8½	9	2½	4	4	4	5½	5½	7
	Heat loss	149	168	200	233	243	269	306	37	63	106	159	178	238	264
	Surface temp.	85	86	88	90	89	89	91	71	74	79	84	84	87	88
12	Thickness	4	5	5½	7	8	8½	9½	2½	4	4	4	5½	5½	7½
	Heat loss	170	191	266	236	262	300	330	42	71	121	181	201	269	284
	Surface temp.	86	86	89	88	88	90	91	71	74	79	85	84	90	88
14	Thickness	4	5	5½	7	8	9	9½	2½	4	4	4	5½	5½	8
	Heat loss	183	205	242	252	262	308	352	47	79	134	199	219	293	293
	Surface temp.	86	87	89	88	88	89	91	72	74	80	85	85	91	87
16	Thickness	4	5½	6½	7½	8	9	10	2½	4	4	4	5½	5½	8
	Heat loss	204	211	237	265	307	338	372	53	88	149	222	242	325	322
	Surface temp.	87	85	86	87	89	90	91	72	75	80	86	86	91	88
18	Thickness	4	5½	6½	7½	8½	9	10	2½	4	4	4	5½	5½	8
	Heat loss	225	232	259	289	320	367	403	59	96	164	245	266	356	351
	Surface temp.	87	86	87	87	88	90	91	72	75	80	86	86	92	88
20	Thickness	4	5½	6½	7½	8½	9½	10	2½	4	4	4½	5½	5½	8
	Heat loss	245	252	281	312	346	381	435	64	105	179	243	289	387	379
	Surface temp.	87	86	87	88	89	90	92	72	75	81	84	86	92	88
24	Thickness	4	5½	6½	7½	8½	9½	10	2½	4	4	5	5½	5½	8
	Heat loss	287	293	325	360	397	437	497	76	123	209	260	336	449	436
	Surface temp.	88	87	88	88	89	90	93	72	75	81	83	87	93	89
30	Thickness	4	5½	7	8	9	10	10	2½	4	4	5½	5½	5½	8
	Heat loss	349	353	368	409	452	498	589	93	150	254	290	405	542	521
	Surface temp.	88	87	87	88	89	90	94	72	75	81	82	87	93	90
36	Thickness	4	6½	7½	8	9	10	10	2½	4	4	5½	5½	5½	8
	Heat loss	410	359	406	475	524	576	681	110	176	229	340	474	635	606
	Surface temp.	89	84	86	88	89	91	94	73	76	81	82	88	94	90
Flat	Thickness	5½	6½	7½	8½	9½	10	10	2½	4	4	5½	5½	7½	8½
	Heat loss	29	33	36	39	43	49	58	11	17	29	31	44	43	50
	Surface temp.	81	83	84	85	87	89	93	73	76	83	84	90	90	93

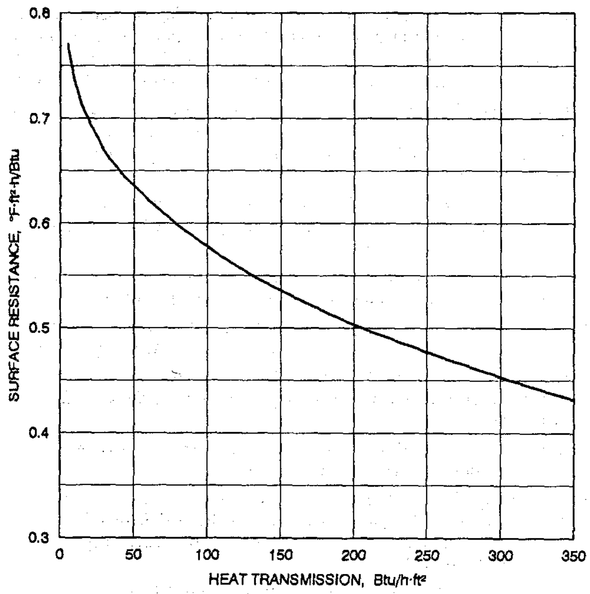


Fig. 9 Surface Resistance as Function of Heat Transmission for Flat Surfaces and Cylindrical Surfaces Greater than 24 in. in Diameter

Because trial and error techniques are tedious, the computer programs previously described should be used to estimate heat flows per unit area of flat surfaces or per unit length of piping, and interface temperatures including surface temperatures.

Several methods can be used to determine the most effective thickness of insulation for piping and equipment. Table 13 shows the recommended insulation thicknesses for three different pipe and equipment insulations. Installed cost data can be developed using procedures described by the Federal Energy Administration (1976). Computer programs capable of calculating thickness information are available from several sources. Also, manufacturers of insulations offer computerized analysis programs for designers and owners to evaluate insulation requirements. For more information on determining economic insulation thickness, see Chapter 22.

Chapters 3 and 22 give guidance concerning process control, personnel protection, condensation control, and economics. For specific information on sizes of commercially available pipe insulation, see ASTM *Standard* C 585 and consult with the North American Insulation Manufacturers Association (NAIMA) and its member companies.

CALCULATING HEAT FLOW FOR BURIED PIPELINES

In calculating heat flow to or from buried pipelines, the thermal properties of the soil must be assumed. Table 7 gives the apparent thermal conductivity values of various soil types, and Figure 8 shows the typical trends of apparent soil thermal conductivity with moisture content for various soil types. Table 8 provides ranges of apparent thermal conductivity for various types of rock. Kernsten (1949) also discusses thermal properties of soils. Carslaw and Jaeger (1959) give methods for calculating the heat flow taking place between one or more buried cylinders and the surroundings.

REFERENCES

Adams, L. 1971. Supporting cryogenic equipment with wood. *Chemical Engineering* (May):156-58.

ASTM. 1990. Standard practice for inner and outer diameters of rigid thermal insulation for nominal sizes of pipe and tubing. *Standard* C585-90. American Society for Testing and Materials, W. Conshohoken, PA.

ASTM. 1991. Standard test method for steady-state heat flux measurements and thermal transmission properties by means of the heat flow meter apparatus. *Standard* C 518-91.

ASTM. 1993. Standard test method for steady-state heat flux measurements and thermal transmission properties by means of the guarded-hot-plate apparatus. *Standard* C 177-85 (Revised 1993).

ASTM. 1993. Standard test method for steady-state thermal performance of building assemblies by means of a guarded hot box. *Standard* C 236-89 (Revised 1993).

ASTM. 1995. Standard practice for determination of heat gain or loss and the surface temperatures of insulated pipe and equipment systems by the use of a computer program. *Standard* C 680-89 (Revised 1995).

ASTM. 1996. Standard test method for thermal performance of building assemblies by means of a calibrated hot box. *Standard* C 976-90 (Revised 1996).

Barbour, E., J. Goodrow, J. Kosny, and J.E. Christian. 1994. Thermal performance of steel-framed walls. Prepared for American Iron and Steel Institute by NAHB Research Center.

Bassett, M.R. and H.A. Trethowen. 1984. Effect of condensation on emittance of reflective insulation. *Journal of Thermal Insulation* 8 (October):127.

Carslaw, H.S. and J.C. Jaeger. 1959. Conduction of heat in solids. Oxford University Press, Amen House, London, England, 449.

Dill, R.S., W.C. Robinson, and H.E. Robinson. 1945. Measurements of heat losses from slab floors. National Bureau of Standards. Building Materials and Structures Report, BMS 103.

Economic thickness for industrial insulation. 1976. GPO No. 41-018-001 15-8, Federal Energy Administration, Washington, D.C.

Farouk, B. and D.C. Larson. 1983. Thermal performance of insulated wall systems with metal studs. Proceedings of the 18th Intersociety Energy Conversion Engineering Conference, Orlando, FL.

Farouki, O.T. 1981. Thermal properties of soil. CRREL *Monograph* 81-1, United States Army Corps of Engineers Cold Regions Research and Engineering Laboratory, December.

Fishenden, M. 1962. Tables of emissivity of surfaces. *International Journal of Heat and Mass Transfer* 5:67-76.

Goss, W.P. and R.G. Miller. 1989. Literature review of measurement and prediction of reflective building insulation system performance: 1900-1989. *ASHRAE Transactions* 95(2).

Hooper, F.C. and W.J. Moroz. 1952. The impact of aging factors on the emissivity of reflective insulations. ASTM *Bulletin* (May):92-95.

Hougten, F.C., S.I. Taimuty, C. Gutberlet, and C.J. Brown. 1942. Heat loss through basement walls and floors. *ASHVE Transactions* 48:369.

Joy, F.A. 1958. Improving attic space insulating values. *ASHAE Transactions* 64:251.

Kersten, M.S. 1949. Thermal properties of soils. University of Minnesota, Engineering Experiment Station Bulletin 28, June.

Kosny, J. and J.E. Christian. 1995. Reducing the uncertainties associated with using the ASHRAE zone method for R-value calculations of metal frame walls. *ASHRAE Transactions* 101(2).

Latta, J.K. and G.G. Boileau. 1969. Heat losses from house basements. *Canadian Building* 19(10).

Lewis, W.C. 1967. Thermal conductivity of wood-base fiber and particle panel materials. Forest Products Laboratory, Research Paper FPL 77, June.

Lotz, W.A. 1964. Vapor barrier design, neglected key to freezer insulation effectiveness. *Quick Frozen Foods* (November):122.

MacLean, J.D. 1941. Thermal conductivity of wood. *ASHVE Transactions* 47:323.

McElroy, D.L., D.W. Yarbrough, and R.S. Graves. 1987. Thickness and density of loose-fill insulations after installation in residential attics. *Thermal insulation: Materials and systems*. F.J. Powell and S.L. Matthews, eds. ASTM STP 922:423-505.

McGowan, A. and A.O. Desjarlais. 1997. An investigation of common thermal bridges in walls. *ASHRAE Transactions* 103(2).

McIntyre, D.A. 1984. The increase in U-value of a wall caused by mortar joints, ECRC/M1843. The Electricity Council Research Centre, Copenhurst, England, June.

Mitalas, G.P. 1982. Basement heat loss studies at DBR/NRC, NRCC 20416. Division of Building Research, National Research Council of Canada, September.

Mitalas, G.P. 1983. Calculation of basement heat loss. *ASHRAE Transactions* 89(1B):420.

Prangnell, R.D. 1971. The water vapor resistivity of building materials—A literature survey. *Materiaux et Constructions* 4:24 (November).

Robinson, H.E., F.J. Powell, and L.A. Cosgrove. 1957. Thermal resistance of airspaces and fibrous insulations bounded by reflective surfaces. National Bureau of Standards, Building Materials and Structures Report BMS 151.

Robinson, H.E., F.J. Powlitch, and R.S. Dill. 1954. The thermal insulation value of airspaces. Housing and Home Finance Agency, Housing Research Paper No. 32.

Sabine, H.J., M.B. Lacher, D.R. Flynn, and T.L. Quindry. 1975. Acoustical and thermal performance of exterior residential walls, doors and windows. *NBS Building Science Series* 77. National Institute of Standards and Technology, Gaithersburg, MD.

Salomone, L.A. and J.I. Marlowe. 1989. Soil and rock classification according to thermal conductivity: Design of ground-coupled heat pump systems. EPRI CU-6482, Electric Power Research Institute, August.

Shipp, P.H. 1983. Basement, crawlspace and slab-on-grade thermal performance. Proceedings of the ASHRAE/DOE Conference, Thermal Performance of the Exterior Envelopes of Buildings II, ASHRAE SP 38:160-79.

Shu, L.S., A.E. Fiorato, and J.W. Howanski. 1979. Heat transmission coefficients of concrete block walls with core insulation. Proceedings of the ASHRAE/DOE-ORNL Conference, Thermal Performance of the Exterior Envelopes of Buildings, ASHRAE SP 28:421-35.

Tye, R.P. 1985. Upgrading thermal insulation performance of industrial processes. *Chemical Engineering Progress* (February):30-34.

Tye, R.P. 1986. Effects of product variability on thermal performance of thermal insulation. Proceedings of the First Asian Thermal Properties Conference, Beijing, People's Republic of China.

Tye, R.P. and A.O. Desjarlais. 1983. Factors influencing the thermal performance of thermal insulations for industrial applications. *Thermal insulation, materials, and systems for energy conservation in the '80s*. F.A. Govan, D.M. Greason, and J.D. McAllister, eds. ASTM STP 789:733-48.

Tye, R.P. and S.C. Spinney. 1980. A study of various factors affecting the thermal performance of perlite insulated masonry construction. Dynatech Report No. PII-2. Holometrix, Inc. (formerly Dynatech R/D Company), Cambridge, MA.

USDA. 1974. *Wood handbook*. Wood as an engineering material. Forest Products Laboratory, U.S. Department of Agriculture Handbook No. 72, Tables 3-7 and 4-2, and Figures 3-4 and 3-5.

Valore, R.C. 1980. Calculation of U-values of hollow concrete masonry. American Concrete Institute, *Concrete International* 2(2):40-62.

Valore, R.C. 1988. Thermophysical properties of masonry and its constituents, Parts I and II. International Masonry Institute, Washington, D.C.

Valore, R., A. Tuluca, and A. Caputo. 1988. Assessment of the thermal and physical properties of masonry block products (ORNL/Sub/86-22020/1), September.

Van Geem, M.G. 1985. Thermal transmittance of concrete block walls with core insulation. *ASHRAE Transactions* 91(2).

Wilkes, K.E. 1979. Thermophysical properties data base activities at Owens-Corning Fiberglas. Proceedings of the ASHRAE/DOE-ORNL Conference, Thermal Performance of the Exterior Envelopes of Buildings, ASHRAE SP 28:662-77.

Yarbrough, E.W. 1983. Assessment of reflective insulations for residential and commercial applications (ORNL/TM-8891), October.

Yellott, J.I. 1965. Thermal and mechanical effects of solar radiation on steel doors. *ASHRAE Transactions* 71(2):42.

Table B-2–Framed Wall Assembly U-Factors

Framing Type and Spacing	Framing Cavity R-Value	Insulated Sheathing R-Value	Wood Wall U-factor	Metal Wall U-factor
2x4 @ 16" O.C.	11 (Compressed)	0	0.098	0.202
		4	0.068	0.112
		5	0.064	0.101
		7	0.056	0.084
		8.7	0.051	0.073
	13	0	0.088	0.195
		4	0.063	0.109
		5	0.059	0.099
		7	0.052	0.082
		8.7	0.048	0.072
	15	0	0.081	0.189
		4	0.059	0.108
		5	0.055	0.097
		7	0.049	0.077
		8.7	0.045	0.071
2x4 @ 24" O.C.	11	0	0.094	0.173
		4	0.066	0.102
		5	0.062	0.093
		7	0.055	0.078
		8.7	0.050	0.069
	13	0	0.085	0.165
		4	0.061	0.099
		5	0.057	0.090
		7	0.051	0.077
		8.7	0.047	0.068
	15	0	0.077	0.158
		4	0.056	0.097
		5	0.053	0.088
		7	0.047	0.071
		8.7	0.044	0.067

Table B-3–Framed Wall Assembly U-Factors (Continued)

Framing Type and Spacing	Framing Cavity R-Value	Insulated Sheathing R-Value	Wood Wall U-factor	Metal Wall U-factor
2x6 @ 16" O.C.	19 (Compressed)	0	0.065	0.120
		4	0.058	0.098
		5	0.048	0.089
		7	0.043	0.075
		8.7	0.040	0.067
	21	0	0.059	0.157
		4	0.046	0.096
		5	0.044	0.088
		7	0.041	0.075
		8.7	0.037	0.066
	22 (Compressed)	0	0.062	0.158
		4	0.048	0.097
		5	0.045	0.088
		7	0.041	0.075
		8.7	0.038	0.067
2x6 @ 24" O.C.	19 (Compressed)	0	0.062	0.135
		4	0.048	0.088
		5	0.045	0.081
		7	0.042	0.070
		8.7	0.039	0.062
	21	0	0.056	0.130
		4	0.044	0.086
		5	0.042	0.079
		7	0.039	0.068
		8.7	0.036	0.061
	22 (Compressed)	0	0.058	0.132
		4	0.046	0.086
		5	0.043	0.079
		7	0.040	0.068
		8.7	0.037	0.061

Table B-2–Framed Wall Assembly U-Factors

Framing Type and Spacing	Framing Cavity R-Value	Insulated Sheathing R-Value	Wood Wall U-factor	Metal Wall U-factor
2x8 @ 16" O.C.	19	0	0.059	0.145
		4	0.047	0.092
		5	0.044	0.084
		7	0.041	0.072
		8.7	0.038	0.064
	22	0	0.054	0.140
		4	0.043	0.090
		5	0.041	0.082
		7	0.038	0.071
		8.7	0.035	0.063
	25	0	0.050	0.136
		4	0.040	0.088
		5	0.038	0.081
		7	0.035	0.070
		8.7	0.033	0.062
	30 (Compressed)	0	0.048	0.135
		4	0.039	0.088
		5	0.037	0.081
		7	0.035	0.070
		8.7	0.032	0.062
2x8 @ 24" O.C.	19	0	0.056	0.122
		4	0.045	0.082
		5	0.043	0.076
		7	0.040	0.066
		8.7	0.037	0.059
	22	0	0.051	0.117
		4	0.041	0.080
		5	0.040	0.074
		7	0.036	0.064
		8.7	0.034	0.058
	25	0	0.047	0.113
		4	0.038	0.078
		5	0.037	0.072
		7	0.034	0.063
		8.7	0.032	0.057
	30 (Compressed)	0	0.046	0.112
		4	0.037	0.077
		5	0.036	0.072
		7	0.034	0.063
		8.7	0.031	0.057

Table B-3–Framed Wall Assembly U-Factors (Continued)

Framing Type and Spacing	Framing Cavity R-Value	Insulated Sheathing R-Value	Wood Wall U-factor	Metal Wall U-factor
2x10 @ 16" O.C.	30	0	0.041	0.120
		4	0.035	0.081
		5	0.033	0.075
		7	0.031	0.065
		8.7	0.029	0.059
	38 (Compressed)	0	0.040	0.119
		4	0.033	0.080
		5	0.032	0.074
		7	0.030	0.065
		8.7	0.028	0.058
2x10 @ 24" O.C.	30 (Compressed)	0	0.039	0.099
		4	0.033	0.071
		5	0.032	0.066
		7	0.030	0.058
		8.7	0.028	0.053
	38	0	0.038	0.097
		4	0.032	0.070
		5	0.031	0.066
		7	0.029	0.058
		8.7	0.027	0.053

Table B-2A–Solar Heat Gain Coefficients Used for Exterior Shading[1]

Exterior Shading Device	***SHGC***
Standard Bug Screens	0.76
Exterior Sunscreens with weave 53*16/inch	0.30
Louvered Sunscreens with louvers as wide as openings	0.27
Low Sun Angle (LSA) Louvered Sunscreens	0.13
Roll-down Awning	0.13
Roll Down Blinds or Slats	0.13
None (for skylights only)	1.00

1 Exterior operable awnings (canvas, plastic or metal), except those that roll vertically down and cover the entire window, should be treated as overhangs for purposes of compliance with the Standards.

Table B-3–Metal Framing Factor

METAL FRAMING FACTORS			
Stud Spacing	Stud Depth	Insulation R-Value	Framing Factor
16" o.c.	4"	R-7	0.522
		R-11	0.403
		R-13	0.362
		R-15	0.328
	6"	R-19	0.325
		R-21	0.300
		R-22	0.287
		R-25	0.263
24" o.c.	4"	R-7	0.577
		R-11	0.458
		R-13	0.415
		R-15	0.379
	6"	R-19	0.375
		R-21	0.348
		R-22	0.335
		R-25	0.308
R-value calculation for Exterior Wall Assemblies with Metal Studs, July, 19, 1990, Staff Draft Docket 90-CON-1.			
*Correction to metal framing factors applies to the entire assembly including: interior air films, interior surfaces, cavity/insulation, exterior surfaces, and exterior air films.			

Table B-4–Properties of Hollow Unit Masonry Walls

Type			Core Treatment		
			Solid Grout	Partly Grouted with Ungrouted Cells: Empty	Insulated
12"	LW CMU	U	0.51	0.43	0.30
		Rw	2.0	2.3	3.3
		HC	23	14.8	14.8
	MW CMU	U	0.54	0.46	0.33
		Rw	1.9	2.2	3.0
		HC	23.9	15.6	15.6
	NW CMU	U	0.57	0.49	0.36
		Rw	1.8	2.0	2.8
		HC	24.8	16.5	16.5
10"	LW CMU	U	0.55	0.46	0.34
		Rw	1.8	2.2	2.9
		HC	18.9	12.6	12.6
	MW CMU	U	0.59	0.49	0.37
		Rw	1.7	2.1	2.7
		HC	19.7	13.4	13.4
	NW CMU	U	0.62	0.52	0.41
		Rw	1.6	1.9	2.4
		HC	20.5	14.2	14.2
8"	LW CMU	U	0.62	0.50	0.37
		Rw	1.6	2.0	2.7
		HC	15.1	9.9	9.9
	MW CMU	U	0.65	0.53	0.41
		Rw	1.5	1.9	2.4
		HC	15.7	10.5	10.5
	NW CMU	U	0.69	0.56	0.44
		Rw	1.4	1.8	2.3
		HC	16.3	11.1	11.1
	Clay Unit	U	0.57	0.47	0.39
		Rw	1.8	2.1	2.6
		HC	15.1	11.4	11.4
6"	LW CMU	U	0.68	0.54	0.44
		Rw	1.5	1.9	2.3
		HC	10.9	7.9	7.9
	MW CMU	U	0.72	0.58	0.48
		Rw	1.4	1.7	2.1
		HC	11.4	8.4	8.4
	NW CMU	U	0.76	0.61	0.52
		Rw	1.3	1.6	1.9
		HC	11.9	8.9	8.9
	Clay Unit	U	0.65	0.52	0.45
		Rw	1.5	1.9	2.2
		HC	11.1	8.6	8.6

Notes:
LW CMU is a Light Weight Concrete Masonry Unit per ASTM C 90, Calculated at 105 PCF density
MW CMU is a Medium Weight Concrete Masonry Unit per ASTM C 90, Calculated at 115 PCF density
NW CMU is a Normal Weight Concrete Masonry Unit per ASTM C 90, Calculated at 125 PCF density
Clay Unit is a Hollow Clay Unit per ASTM C 652, Calculated at 130 PCF density
Values include air films on inner and outer surfaces.
Calculations based on Energy Calculations and Data, CMACN, 1986
Grouted Cells at 32" X 48" in Partly Grouted Walls
Source: Berkeley Solar Group; Concrete Masonry Association of California and Nevada

Table B-5–Properties of Solid Unit Masonry and Solid Concrete Walls

Type		Layer Thickness, inches									
		3	4	5	6	7	8	9	10	11	12
LW CMU	U	na	0.71	0.64	na	na	na	na	na	na	na
	Rw	na	1.4	1.6	na	na	na	na	na	na	na
	HC	na	7.00	8.75	na	na	na	na	na	na	na
MW CMU	U	na	0.76	0.70	na	na	na	na	na	na	na
	Rw	na	1.3	1.4	na	na	na	na	na	na	na
	HC	na	7.67	9.58	na	na	na	na	na	na	na
NW CMU	U	0.89	0.82	0.76	na	na	na	na	na	na	na
	Rw	1.1	1.2	1.3	na	na	na	na	na	na	na
	HC	6.25	8.33	10.42	na	na	na	na	na	na	na
Clay Brick	U	0.80	0.72	0.66	na	na	na	na	na	na	na
	Rw	1.3	1.4	1.5	na	na	na	na	na	na	na
	HC	6.30	8.40	10.43	na	na	na	na	na	na	na
Concrete	U	0.96	0.91	0.86	0.82	0.78	0.74	0.71	0.68	0.65	0.63
	Rw	1.0	1.1	1.2	1.2	1.3	1.4	1.4	1.5	1.5	1.6
	HC	7.20	9.60	12.00	14.40	16.80	19.20	21.60	24.00	26.40	28.80

Notes:
LW CMU is a Light Weight Concrete Masonry Unit per ASTM C 90 or 55, Calculated at 105 PCF density
MW CMU is a Medium Weight Concrete Masonry Unit per ASTM C 90 or 55, Calculated at 115 PCF density
NW CMU is a Normal Weight Concrete Masonry Unit per ASTM C 90 or 55, Calculated at 125 PCF density
Clay Brick is a Clay Unit per ASTM C 62, Calculated at 130 PCF density
Concrete is structural poured or precast concrete, Calculated at 144 PCF density
Calculations based on Energy Calculations and Data, CMACN, 1986
Values include air films on inner and outer surfaces.
Source: Berkeley Solar Group; Concrete Masonry Association of California and Nevada

Table B-6–Effective R-values for Interior Insulation Layers on Structural Mass Walls

Type Actual Thick	Frame	Furring space R-value without framing effects																					
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Any	None	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5
0.5"	Wood	1.3	1.3	1.9	2.4	2.7	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	Metal	0.9	0.9	1.1	1.1	1.2	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
0.75"	Wood	1.4	1.4	2.1	2.7	3.1	3.5	3.8	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	Metal	1.0	1.0	1.3	1.4	1.5	1.5	1.6	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
1.0"	Wood	1.3	1.5	2.2	2.9	3.4	3.9	4.3	4.6	4.9	na	na	na	na	na	na	na	na	na	na	na	na	na
	Metal	1.0	1.1	1.4	1.6	1.7	1.8	1.8	1.9	1.9	na	na	na	na	na	na	na	na	na	na	na	na	na
1.5"	Wood	1.3	1.5	2.4	3.1	3.8	4.4	4.9	5.4	5.8	6.2	6.5	6.8	7.1	na	na	na	na	na	na	na	na	na
	Metal	1.1	1.2	1.6	1.9	2.1	2.2	2.3	2.4	2.5	2.5	2.6	2.6	2.7	na	na	na	na	na	na	na	na	na
2"	Wood	1.4	1.5	2.5	3.3	4.0	4.7	5.3	5.9	6.4	6.9	7.3	7.7	8.1	8.4	8.7	9.0	9.3	na	na	na	na	na
	Metal	1.1	1.2	1.7	2.1	2.3	2.5	2.7	2.8	2.9	3.0	3.1	3.2	3.2	3.3	3.3	3.4	3.4	na	na	na	na	na
2.5"	Wood	1.4	1.5	2.5	3.4	4.2	4.9	5.6	6.3	6.8	7.4	7.9	8.4	8.8	9.2	9.6	10.0	10.3	10.6	10.9	11.2	11.5	na
	Metal	1.2	1.3	1.8	2.3	2.6	2.8	3.0	3.2	3.3	3.5	3.6	3.6	3.7	3.8	3.9	3.9	4.0	4.0	4.1	4.1	4.1	na
3"	Wood	1.4	1.5	2.5	3.5	4.3	5.1	5.8	6.5	7.2	7.8	8.3	8.9	9.4	9.9	10.3	10.7	11.1	11.5	11.9	12.2	12.5	12.9
	Metal	1.2	1.3	1.9	2.4	2.8	3.1	3.3	3.5	3.7	3.8	4.0	4.1	4.2	4.3	4.4	4.4	4.5	4.6	4.6	4.7	4.7	4.8
3.5"	Wood	1.4	1.5	2.6	3.5	4.4	5.2	6.0	6.7	7.4	8.1	8.7	9.3	9.8	10.4	10.9	11.3	11.8	12.2	12.6	13.0	13.4	13.8
	Metal	1.2	1.3	2.0	2.5	2.9	3.2	3.5	3.8	4.0	4.2	4.3	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.1	5.2	5.2	5.3
4"	Wood	1.4	1.6	2.6	3.6	4.5	5.3	6.1	6.9	7.6	8.3	9.0	9.6	10.2	10.8	11.3	11.9	12.4	12.8	13.3	13.7	14.2	14.6
	Metal	1.2	1.3	2.0	2.6	3.0	3.4	3.7	4.0	4.2	4.5	4.6	4.8	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.8
4.5"	Wood	1.4	1.6	2.6	3.6	4.5	5.4	6.2	7.1	7.8	8.5	9.2	9.9	10.5	11.2	11.7	12.3	12.8	13.3	13.8	14.3	14.8	15.2
	Metal	1.2	1.3	2.1	2.6	3.1	3.5	3.9	4.2	4.5	4.7	4.9	5.1	5.3	5.4	5.6	5.7	5.8	5.9	6.0	6.1	6.2	6.3
5"	Wood	1.4	1.6	2.6	3.6	4.6	5.5	6.3	7.2	8	8.7	9.4	10.1	10.8	11.5	12.1	12.7	13.2	13.8	14.3	14.8	15.3	15.8
	Metal	1.2	1.4	2.1	2.7	3.2	3.7	4.1	4.4	4.7	5.0	5.2	5.4	5.6	5.8	5.9	6.1	6.2	6.3	6.5	6.6	6.7	6.8
5.5"	Wood	1.4	1.6	2.6	3.6	4.6	5.5	6.4	7.3	8.1	8.9	9.6	10.3	11.0	11.7	12.4	13.0	13.6	14.2	14.7	15.3	15.8	16.3
	Metal	1.3	1.4	2.1	2.8	3.3	3.8	4.2	4.6	4.9	5.2	5.4	5.7	5.9	6.1	6.3	6.4	6.6	6.7	6.8	7.0	7.1	7.2

All furring thickness values given are actual dimensions

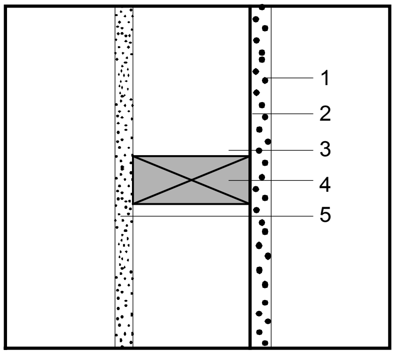
All values include .5" gypboard on the inner surface, interior surface resistances not included

- 24" OC Furring
- 24 Gage, Z-type Metal Furring
- Douglas-Fir Larch Wood Furring, density = 34.9 lb/cu.ft
- Insulation assumed to fill the furring space

[Source: Berkeley Solar Group; Concrete Masonry Association of California and Nevada]

Table B-7–Framed Wall/Floor/Ceiling Assembly U-Factors

Reference Name: **W.0.2x4.16**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor	
	✓	Wall	
		Ceiling/Roof	
Framing Material:	**Wood**		
Framing Size:	2 × 4		
Framing Spacing:	16 "o.c.		
Framing (check one)	Wall:	✓	15%
			12%
			9% (48"o.c.)
	Floor/Ceilin		10%
			7% (24"o.c.)
			4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA		

List of Construction Components / **R-Value**

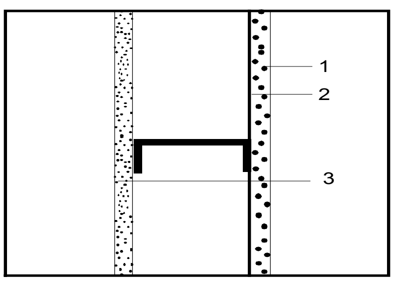
	List of Construction Components	Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.180	0.180
2.	Building paper (felt)	0.060	0.060
3.	3.5" & greater air space; heat sideways	0.850	-----
4.	2x4 in fir framing	-----	3.465
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	2.390	5.005
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\frac{1/2.390}{1 \div R_c}\right) \times \left(\frac{1-15/100}{1-(\text{Fr.}\% \div 100)}\right)\right] + \left[\left(\frac{1/5.005}{1 \div R_f}\right) \times \left(\frac{15/100}{\text{Fr.}\% \div 100}\right)\right] = \boxed{0.385}\ \textbf{Total U-factor}$$

$$\frac{1/0.385}{1 \div \text{Total U-factor}} = 2.593\ \textbf{Total R-Value}$$

Reference Name: **W.0.S2x4.16**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor	
	✓	Wall	
		Ceiling/Roof	
Framing Material:	**Metal**		
Framing Spacing:	16 "o.c.		
Framing Size:		Actual Depth	3.625
		Actual Width	1.625
Cavity Insulation:		R-value	0.850
		Knock-out (%)	15.00
		Web	0.060
Insulation Tape R-		Interior Flange	0.0
		Exterior	0.0

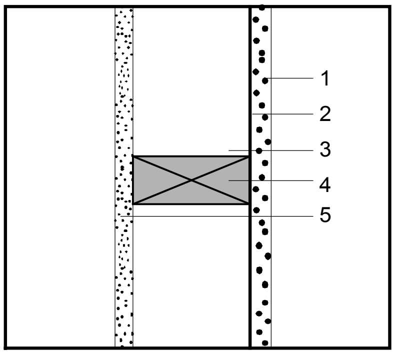
	List of Construction Components	R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.180
2.	Building paper (felt)	0.060
3.	0.50 in gypsum or plaster board	0.450
4.		
5.		
6.		
7.		
	Inside Surface Air Film	0.680

Calculation:

From EZFRAME = $\boxed{0.449}$ **Total U-factor**

$$\frac{1/0.449}{1 \div \text{Total U-factor}} = 2.23\ \textbf{Total R-Value}$$

Reference Name: **W.0.2x4.24**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor	
	✓	Wall	
		Ceiling/Roof	
Framing Material:	**Wood**		
Framing Size:	2 × 4		
Framing Spacing:	24 "o.c.		
Framing (check one)	Wall:		15%
			12%
			9% (48"o.c.)
	Floor/Ceilin		10%
			7% (24"o.c.)
			4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA		

List of Construction Components

		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.180	0.180
2.	Building paper (felt)	0.060	0.060
3.	3.5" & greater air space: heat sideways	0.850	-----
4.	2x4 in fir framing	-----	3.465
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	2.390	5.005
		R_c	R_f

Framing Adjustment Calculation:

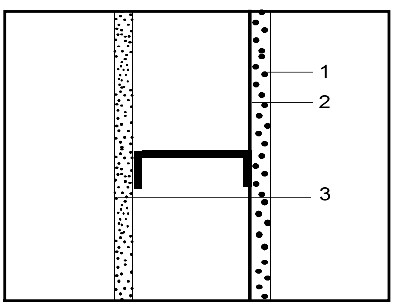
$$\left[\left(\underset{1\div R_c}{1/2.390}\right) \times \left(\underset{1-(\text{Fr.}\% \div 100)}{1-12/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/5.005}\right) \times \left(\underset{\text{Fr.}\% \div 100}{12/100}\right)\right] = \boxed{0.392}$$

Total U-factor

$$\underset{1\div\text{Total U-factor}}{1/0.392} = 2.549$$

Total R-Value

Reference Name: **W.0.S2x4.24**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor	
	✓	Wall	
		Ceiling/Roof	
Framing Material:	**Metal**		
Framing Spacing:	24 "o.c.		
Framing Size:		Actual Depth	3.625
		Actual Width	1.625
Cavity Insulation:		R-value	0.850
		Knock-out (%)	15.00
		Web	0.060
Insulation Tape R-		Interior Flange	0.0
		Exterior	0.0

List of Construction Components

		R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.180
2.	Building paper (felt)	0.060
3.	0.50 in gypsum or plaster board	0.450
4.		
5.		
6.		
7.		
	Inside Surface Air Film	0.680

Calculation:

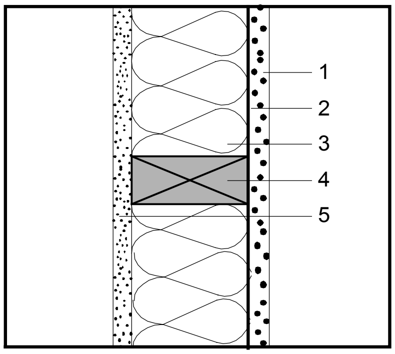
From EZFRAME = $\boxed{0.443}$

Total U-factor

$$\underset{1\div\text{Total U-factor}}{1/0.443} = 2.260$$

Total R-Value

Reference Name: **W.7.2x4.16**



Sketch of Construction Assembly

Assembly Type:			Floor
(check one)	✓		Wall
			Ceiling/Roof
Framing Material:	**Wood**		
Framing Size:	2	×	4
Framing Spacing:	16	"o.c.	
Framing (check one)	Wall:	✓	15%
			12%
			9% (48"o.c.)
	Floor/Ceilin		10%
			7% (24"o.c.)
			4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA		

List of Construction Components — **R-Value**

		Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.180	0.180
2.	Building paper (felt)	0.060	0.060
3.	R-7 fiberglass insulation	7.000	-----
4.	2x4 in fir framing	-----	3.465
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	8.540	5.005
		R_c	R_f

Framing Adjustment Calculation:

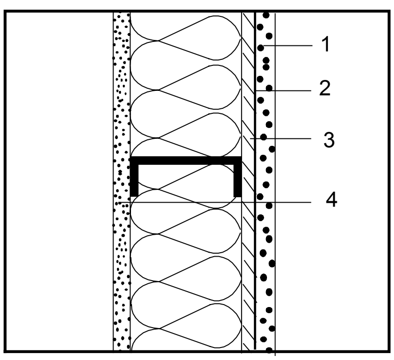
$$\left[\left(\underset{1\div R_c}{1/8.540}\right) \times \left(\underset{1-(\text{Fr.\%} \div 100)}{1-15/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/5.005}\right) \times \left(\underset{\text{Fr.\%} \div 100}{15/100}\right)\right] = \boxed{0.130}$$

Total U-factor

$$\underset{1\div\text{Total U-factor}}{1/0.130} = 7.69$$

Total R-Value

Reference Name: **W.7.S2x4.16**



Sketch of Construction Assembly

Assembly Type:			Floor
(check one)	✓		Wall
			Ceiling/Roof
Framing Material:	**Metal**		
Framing Spacing:	16	"o.c.	
Framing Size:	Actual Depth	3.625	
	Actual Width	1.625	
Cavity Insulation:	R-value	7.00	
	Knock-out (%)	15.00	
	Web	0.060	
Insulation Tape R-	Interior Flange	0.0	
	Exterior	0.0	

List of Construction Components — **R-Value**

		R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.180
2.	Building paper (felt)	0.060
3.	0.50 in polyisocyanurate	3.520
4.	0.50 in gypsum or plaster board	0.450
5.		
6.		
7.		
	Inside Surface Air Film	0.680

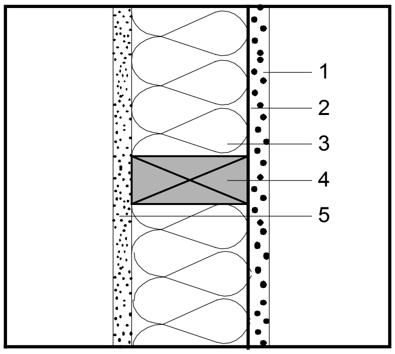
Calculation:

From EZFRAME = $\boxed{0.125}$ **Total U-factor**

$$\underset{1\div\text{Total U-factor}}{1/0.125} = 7.990$$

Total R-Value

Reference Name: **W.7.2x4.24**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor	
	✓	Wall	
		Ceiling/Roof	
Framing Material:	**Wood**		
Framing Size:	2 × 4		
Framing Spacing:	24 "o.c.		
Framing (check one)	Wall:		15%
		✓	12%
			9% (48"o.c.)
	Floor/Ceilin		10%
			7% (24"o.c.)
			4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA		

List of Construction Components

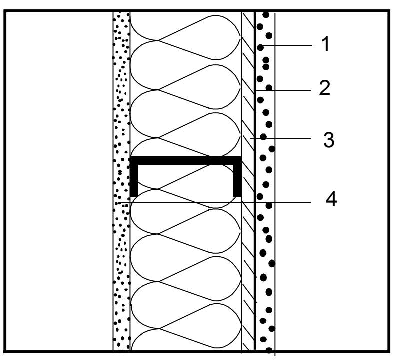
		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.180	0.180
2.	Building paper (felt)	0.060	0.060
3.	R-7 Fiberglass Insulation	7.000	-----
4.	2x4 in fir framing	-----	3.465
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	8.540	5.005
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\underset{1\div R_c}{1/8.540}\right) \times \left(\underset{1-(\text{Fr.\%} \div 100)}{1-12/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/5.005}\right) \times \left(\underset{\text{Fr.\%} \div 100}{12/100}\right)\right] = \underset{\textbf{Total U-factor}}{\boxed{0.127}}$$

$$\underset{1\div\text{Total U-factor}}{1/0.127} = \underset{\textbf{Total R-Value}}{7.874}$$

Reference Name: **W.7.S2x4.24**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor	
	✓	Wall	
		Ceiling/Roof	
Framing Material:	**Metal**		
Framing Spacing:	24 "o.c.		
Framing Size:		Actual Depth	3.625
		Actual Width	1.625
Cavity Insulation:		R-value	7.000
		Knock-out (%)	15.000
		Web	0.060
Insulation Tape R-		Interior Flange	0.0
		Exterior	0.0

List of Construction Components

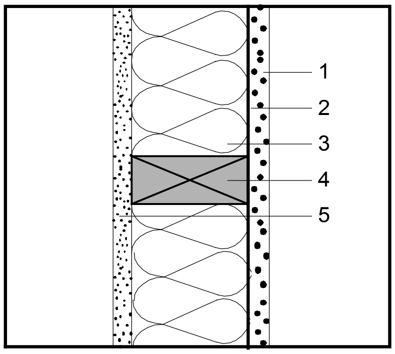
		R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.180
2.	Building paper (felt)	0.060
3.	0.50 in polyisocyanurate	3.520
4.	0.50 in gypsum or plaster board	0.450
5.		
6.		
7.		
	Inside Surface Air Film	0.680

Calculation:

From EZFRAME = $\underset{\textbf{Total U-factor}}{\boxed{0.117}}$

$$\underset{1\div\text{Total U-factor}}{1/0.117} = \underset{\textbf{Total R-Value}}{8.530}$$

Reference Name: **W.11.2x4.16**



Sketch of Construction Assembly

Assembly Type: (check one)			Floor
	✓		Wall
			Ceiling/Roof
Framing Material:	**Wood**		
Framing Size:	2	×	4
Framing Spacing:	16	"o.c.	
Framing (check one)	Wall:	✓	15%
			12%
			9% (48"o.c.)
	Floor/Ceilin		10%
			7% (24"o.c.)
			4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA		

List of Construction Components / **R-Value**

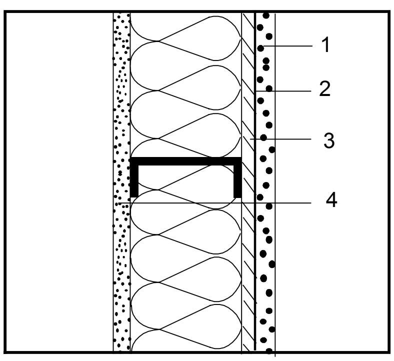
		Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.180	0.180
2.	Building paper (felt)	0.060	0.060
3.	R-11 fiberglass insulation	11.000	-----
4.	2x4 in fir framing	-----	3.465
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	12.540	5.005
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\underset{1\div R_c}{1/12.540}\right) \times \left(\underset{1-(\text{Fr.}\% \div 100)}{1-15/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/5.005}\right) \times \left(\underset{\text{Fr.}\% \div 100}{15/100}\right)\right] = \boxed{0.098}\ \textbf{Total U-factor}$$

$$\underset{1\div \text{Total U-factor}}{1/0.098} = 10.204\ \textbf{Total R-Value}$$

Reference Name: **W.11.S2x4.16**



Sketch of Construction Assembly

Assembly Type: (check one)			Floor
	✓		Wall
			Ceiling/Roof
Framing Material:	**Metal**		
Framing Spacing:	16	"o.c.	
Framing Size:		Actual Depth	3.625
		Actual Width	1.625
Cavity Insulation:		R-value	11.000
		Knock-out (%)	15.000
		Web	0.060
Insulation Tape R-		Interior Flange	0.0
		Exterior	0.0

List of Construction Components / **R-Value**

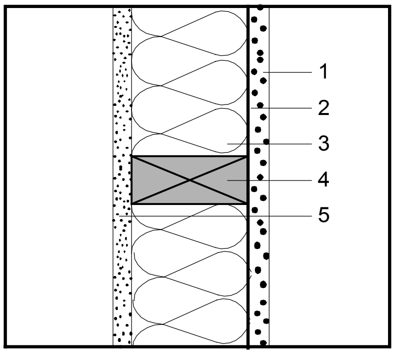
		R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.180
2.	Building paper (felt)	0.060
3.	0.75 in polyisocyanurate	5.280
4.	0.50 in gypsum or plaster board	0.450
5.		
6.		
7.		
	Inside Surface Air Film	0.680

Calculation:

From EZFRAME = $\boxed{0.096}$ **Total U-factor**

$$\underset{1\div \text{Total U-factor}}{1/0.096} = 10.360\ \textbf{Total R-Value}$$

Reference Name: **W.11.2x4.24**



Sketch of Construction Assembly

Assembly Type:		Floor	
(check one)	✓	Wall	
		Ceiling/Roof	
Framing Material:	**Wood**		
Framing Size:	2	×	4
Framing Spacing:	24	"o.c.	
Framing	Wall:	✓	15%
(check one)			12%
			9% (48"o.c.)
	Floor/Ceilin		10%
			7% (24"o.c.)
			4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA		

List of Construction Components

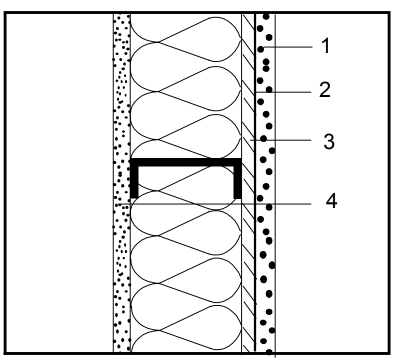
	List of Construction Components	R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.180	0.180
2.	Building paper (felt)	0.060	0.060
3.	R-11 fiberglass insulation	11.000	-----
4.	2x4 in fir framing	-----	3.465
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	12.540	5.005
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\frac{1/12.540}{1\div R}\right) \times \left(\frac{1-12/100}{1-(\text{Fr.}\%\div 100)}\right)\right] + \left[\left(\frac{1/5.005}{1\div R_f}\right) \times \left(\frac{12/100}{\text{Fr.}\%\div 100}\right)\right] = \boxed{0.094}\ \textbf{Total U-factor}$$

$$\frac{1/0.094}{1\div\text{Total U-factor}} = 10.638\ \textbf{Total R-Value}$$

Reference Name: **W.11.S2x4.24**



Sketch of Construction Assembly

Assembly Type:			Floor
(check one)		✓	Wall
			Ceiling/Roof
Framing Material:		**Metal**	
Framing Spacing:		24	"o.c.
Framing Size:	Actual Depth	3.625	
	Actual Width	1.625	
Cavity Insulation:	R-value	11.000	
	Knock-out (%)	15.000	
	Web	0.060	
Insulation Tape R-	Interior Flange	0.0	
	Exterior	0.0	

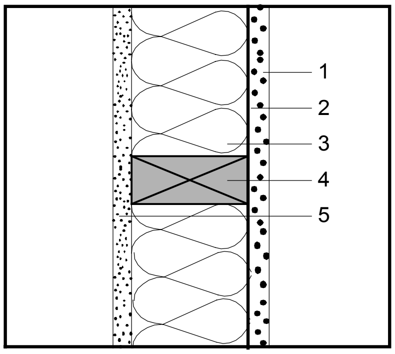
	List of Construction Components	R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.180
2.	Building paper (felt)	0.060
3.	0.75 in polyisocyanurate	5.280
4.	0.50 in gypsum or plaster board	0.450
5.		
6.		
7.		
	Inside Surface Air Film	0.680

Calculation:

From EZFRAME = $\boxed{0.090}$ **Total U-factor**

$$\frac{1/0.090}{1\div\text{Total U-factor}} = 11.140\ \textbf{Total R-Value}$$

Reference Name: **W.13.2x4.16**



Sketch of Construction Assembly

Assembly Type:		Floor
(check one)	✓	Wall
		Ceiling/Roof
Framing Material:	Wood	
Framing Size:	2 × 4	
Framing Spacing:	16 "o.c.	
Framing (check one)	Wall: ✓	15%
		12%
		9% (48"o.c.)
	Floor/Ceilin	10%
		7% (24"o.c.)
		4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA	

List of Construction Components		R-Value Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.180	0.180
2.	Building paper (felt)	0.060	0.060
3.	R-13 fiberglass insulation	13.000	-----
4.	2x4 in fir framing	-----	3.465
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	14.540	5.005
		R_c	R_f

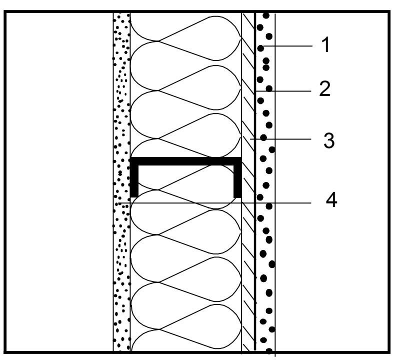
Framing Adjustment Calculation:

[(1/14.540) × (1-15/100)] + [(1/5.005) × (15/100)] = **0.088** **Total U-factor**

$1 \div R_c$ — 1-(Fr.% ÷100) — $1 \div R_f$ — Fr.% ÷100

1/0.088 (1÷Total U-factor) = 11.364 **Total R-Value**

Reference Name: **W.13.S2x4.16**



Sketch of Construction Assembly

Assembly Type:		Floor
(check one)	✓	Wall
		Ceiling/Roof
Framing Material:	Metal	
Framing Spacing:	16 "o.c.	
Framing Size:	Actual Depth	3.625
	Actual Width	1.625
Cavity Insulation:	R-value	13.000
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	0.0
	Exterior	0.0

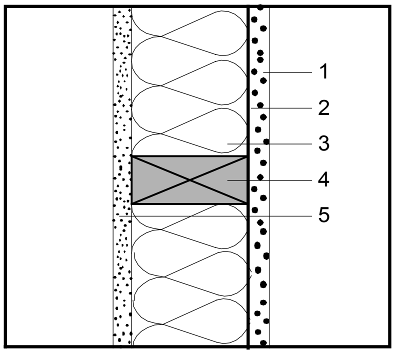
List of Construction Components		R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.180
2.	Building paper (felt)	0.060
3.	1.00 in Polyisocyanurate	7.040
4.	0.50 in gypsum or plaster board	0.450
5.		
6.		
7.		
	Inside Surface Air Film	0.680

Calculation:

From EZFRAME = **0.081** **Total U-factor**

1/0.081 (1÷Total U-factor) = 12.330 **Total R-Value**

Reference Name: **W.13.2x4.24**



Sketch of Construction Assembly

Assembly Type:			Floor
(check one)	✓		Wall
			Ceiling/Roof
Framing Material:	**Wood**		
Framing Size:	2	×	4
Framing Spacing:	24	"o.c.	
Framing	Wall:	✓	15%
(check one)			12%
			9% (48"o.c.)
	Floor/Ceilin		10%
			7% (24"o.c.)
			4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA		

List of Construction Components

		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.180	0.180
2.	Building paper (felt)	0.060	0.060
3.	R-13 fiberglass insulation	13.000	-----
4.	2x4 in fir framing	-----	3.465
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	14.540	5.005
		R_c	R_f

Framing Adjustment Calculation:

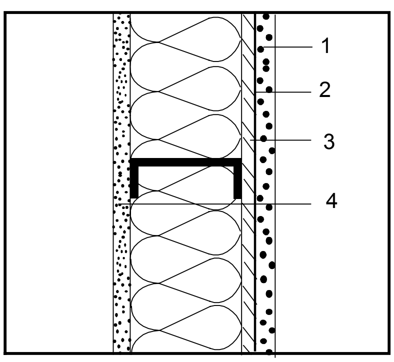
$$\left[\left(\frac{1/14.540}{1\div R_c}\right) \times \left(\frac{1-12/100}{1-(\text{Fr.\%} \div 100)}\right)\right] + \left[\left(\frac{1/5.005}{1\div R_f}\right) \times \left(\frac{12/100}{\text{Fr.\%} \div 100}\right)\right] = \boxed{0.084}$$

Total U-factor

$$\frac{1/0.084}{1\div\text{Total U-factor}} = 11.905$$

Total R-Value

Reference Name: **W.13.S2x4.24**



Sketch of Construction Assembly

Assembly Type:			Floor
(Check one)	✓		Wall
			Ceiling/Roof
Framing Material:	**Metal**		
Framing Spacing:	24	"o.c.	
Framing Size:	Actual Depth	3.625	
	Actual Width	1.625	
Cavity Insulation:	R-value	13.00	
	Knock-out (%)	15.00	
	Web	0.060	
Insulation Tape R-	Interior Flange	0.0	
	Exterior	0.0	

List of Construction Components

		R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.180
2.	Building paper (felt)	0.060
3.	0.75 in polyisocyanurate	5.280
4.	0.50 in gypsum or plaster board	0.450
5.		
6.		
7.		
	Inside Surface Air Film	0.680

Calculation:

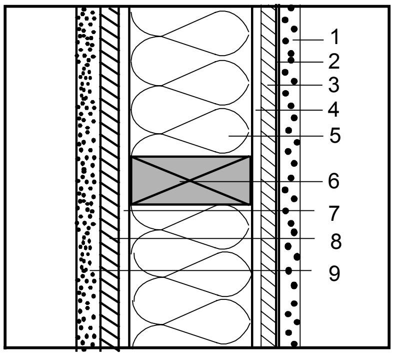
From EZFRAME = $\boxed{0.087}$

Total U-factor

$$\frac{1/0.087}{1\div\text{Total U-factor}} = 11.460$$

Total R-Value

Reference Name: **WP.14.2x4.48**



Sketch of Construction Assembly

Assembly Type:		Floor
(check one)	✓	Wall
		Ceiling/Roof
Framing Material:	**Wood**	
Framing Size:	2 × 4	
Framing Spacing:	48 "o.c.	

Framing (check one)	Wall:		15%
			12%
		✓	9% (48"o.c.)
	Floor/Ceilin		10%
			7% (24"o.c.)
			4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components

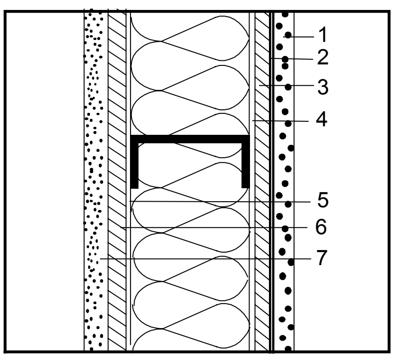
		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.180	0.180
2.	Building paper (felt)	0.060	0.060
3.	0.375 in plywood	0.470	0.470
4.	0.875 in Furring Channel	0.800	0.800
5.	3 5/8 in EPS foam insulation @ R-3.85/in	13.956	-----
6.	2x4 in fir framing	-----	3.465
7.	0.875 in Furring Channel	0.800	0.800
8.	0.375 in plywood	0.470	0.470
9.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	18.036	7.545
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\underset{1\div R_c}{1/18.036}\right) \times \left(\underset{1-(\text{Fr.\%} \div 100)}{1-9/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/7.545}\right) \times \left(\underset{\text{Fr.\%} \div 100}{9/100}\right)\right] = \boxed{0.062}\ \textbf{Total U-factor}$$

$$\underset{1\div\text{Total U-factor}}{1/0.062} = 16.129\ \textbf{Total R-Value}$$

Reference Name: **WP.14.S2x4.48**



Sketch of Construction Assembly

Assembly Type:		Floor
(check one)	✓	Wall
		Ceiling/Roof
Framing Material:	**Metal**	
Framing Spacing:	48 "o.c.	
Framing Size:	Actual Depth	3.625
	Actual Width	1.625
Cavity Insulation:	R-value	14.00
	Knock-out (%)	15.00
	Web	0.060
Insulation Tape R-	Interior Flange	0.0
	Exterior	0.0

List of Construction Components

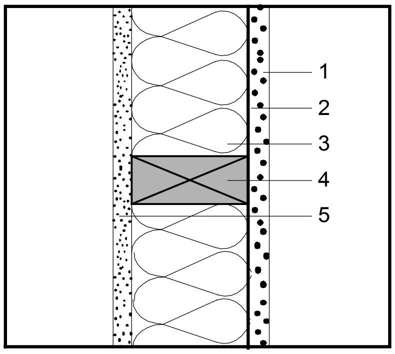
		R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.180
2.	Building paper (felt)	0.060
3.	1.00 in polyisocyanurate	7.040
4.	0.875 in Furring Channel	0.800
5.	0.875 in Furring Channel	0.800
6.	0.375 in plywood	0.470
7.	0.50 in gypsum or plaster board	0.450
	Inside Surface Air Film	0.680

Calculation:

From EZFRAME $= \boxed{0.062}$ **Total U-factor**

$$\underset{1\div\text{Total U-factor}}{1/0.062} = 16.26\ \textbf{Total R-Value}$$

Reference Name: **W.15.2x4.16**



Sketch of Construction Assembly

Assembly Type: (check one)

	Floor
✓	Wall
	Ceiling/Roof

Framing Material: **Wood**
Framing Size: 2 4
Framing Spacing: 16 "o.c.
Framing (check one)

Wall:		15%
	✓	12%
		9% (48"o.c.)
Floor/Ceilin		10%
		7% (24"o.c.)
		4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components | **R-Value**

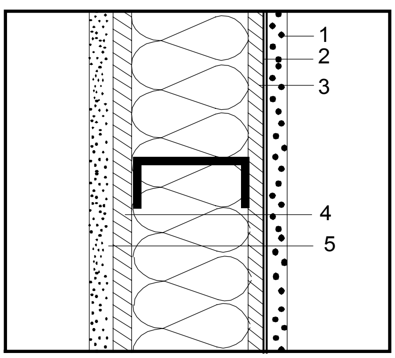
	List of Construction Components	Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.180	0.180
2.	Building paper (felt)	0.060	0.060
3.	R-15 fiberglass insulation	15.000	-----
4.	2x4 in fir framing	-----	3.465
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	16.540	5.005
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\underset{1\div R}{1/16.540}\right) \times \left(\underset{1-(\text{Fr.\%} \div 100)}{1-15/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/5.005}\right) \times \left(\underset{\text{Fr.\%} \div 100}{15/100}\right)\right] = \underset{\textbf{Total U-factor}}{\boxed{\mathbf{0.081}}}$$

$$\underset{1\div\text{Total U-factor}}{1/0.081} = \underset{\textbf{Total R-Value}}{12.346}$$

Reference Name: **W.15.S2x4.16**



Sketch of Construction Assembly

Assembly Type: (check one)

	Floor
✓	Wall
	Ceiling/Roof

Framing Material: **Metal**
Framing Spacing: 16 "o.c.

Framing Size:	Actual Depth	3.625
	Actual Width	1.625
Cavity Insulation:	R-value	15.00
	Knock-out (%)	15.00
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

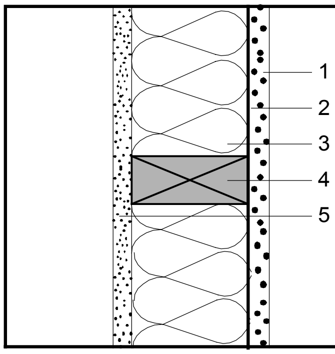
	List of Construction Components	R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.180
2.	Building paper (felt)	0.060
3.	0.50 in Polyisocyanurate	3.520
4.	0.50 in Polyisocyanurate	3.520
5.	0.50 in gypsum or plaster board	0.450
6.		
7.		
	Inside Surface Air Film	0.680

Calculation:

From EZFRAME = **0.080** **Total U-factor**

$$\underset{1\div\text{Total U-factor}}{1/0.080} = \underset{\textbf{Total R-Value}}{12.510}$$

Reference Name: **W.15.2x4.24**



Sketch of Construction Assembly

Assembly Type: (check one)	✓	Floor
		Wall
		Ceiling/Roof
Framing Material:	Wood	
Framing Size:	2	4
Framing Spacing:	24	× "o.c.
Framing (check one)	Wall:	15%
		12%
	✓	9% (48"o.c.)
	Floor/Ceilin	10%
		7% (24"o.c.)
		4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA	

List of Construction Components

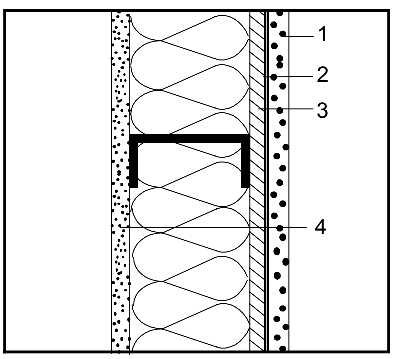
		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.180	0.180
2.	Building paper (felt)	0.060	0.060
3.	R-15 fiberglass insulation	15.000	-----
4.	2x4 in fir framing	-----	3.465
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	16.540	5.005
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\frac{1/16.540}{1 \div R_c}\right) \times \left(\frac{1-12/100}{1-(\text{Fr.\%} \div 100)}\right)\right] + \left[\left(\frac{1/5.005}{1 \div R_f}\right) \times \left(\frac{12/100}{\text{Fr.\%} \div 100}\right)\right] = \boxed{0.077} \text{ Total U-factor}$$

$$\frac{1/0.077}{1 \div \text{Total U-factor}} = 12.987 \text{ Total R-Value}$$

Reference Name: **W.15.S2x4.24**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
	✓	Wall
		Ceiling/Roof
Framing Material:	Metal	
Framing Spacing:	24	"o.c.
Framing Size:	Actual Depth	3.625
	Actual Width	1.625
Cavity Insulation:	R-value	15.00
	Knock-out (%)	15.00
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components

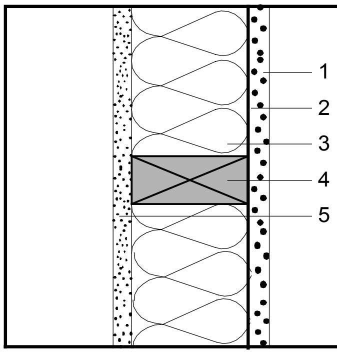
		R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.180
2.	Building paper (felt)	0.060
3.	1 in Polyisocyanurate	7.040
4.	0.50 in gypsum or plaster board	0.450
5.		
6.		
7.		
	Inside Surface Air Film	0.680

Calculation:

From EZFRAME = $\boxed{0.074}$ **Total U-factor**

$$\frac{1/0.074}{1 \div \text{Total U-factor}} = 13.470 \text{ Total R-Value}$$

Reference Name: **W.19.2x6.16**



Sketch of Construction Assembly

Assembly Type:		Floor	
(check one)	✓	Wall	
		Ceiling/Roof	
Framing Material:	**Wood**		
Framing Size:	2 × 6		
Framing Spacing:	16 "o.c.		
Framing (check one)	Wall:	✓	15%
			12%
			9% (48"o.c.)
	Floor/Ceilin		10%
			7% (24"o.c.)
			4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA		

List of Construction Components

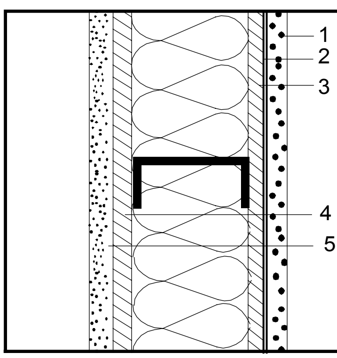
		Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.180	0.180
2.	Building paper (felt)	0.060	0.060
3.	R-19 fiberglass inuslation	19.000	-----
4.	2x6 in fir framing	-----	5.445
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	20.540	6.985
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\underset{1\div R_c}{1/20.540}\right) \times \left(\underset{1-(\text{Fr.}\% \div 100)}{1-15/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/6.985}\right) \times \left(\underset{\text{Fr.}\% \div 100}{15/100}\right)\right] = \boxed{0.063}\ \textbf{Total U-factor}$$

$$\underset{1\div\text{Total U-factor}}{1/0.063} = 15.873\ \textbf{Total R-Value}$$

Reference Name: **W.19.S2x6.16**



Sketch of Construction Assembly

Assembly Type:		Floor	
(check one)	✓	Wall	
		Ceiling/Roof	
Framing Material:	**Metal**		
Framing Spacing:	16 "o.c.		
Framing Size:		Actual Depth	6.000
		Actual Width	1.625
Cavity Insulation:		R-value	19.00
		Knock-out (%)	15.00
		Web	0.060
Insulation Tape R-		Interior Flange	
		Exterior	

List of Construction Components

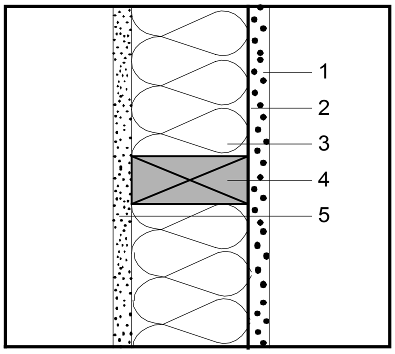
		R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.180
2.	Building paper (felt)	0.060
3.	0.75 in polyiscyanurate	5.280
4.	0.50 in polyiscyanurate	3.520
5.	0.50 in gypsum or plaster board	0.450
6.		
7.		
	Inside Surface Air Film	0.680

Calculation:

From EZFRAME = $\boxed{0.064}$ **Total U-factor**

$$\underset{1\div\text{Total U-factor}}{1/0.064} = 15.530\ \textbf{Total R-Value}$$

Reference Name: **W.19.2x6.24**



Sketch of Construction Assembly

Assembly Type: (check one)			Floor
	✓		Wall
			Ceiling/Roof
Framing Material:	Wood		
Framing Size:	2 × 6		
Framing Spacing:	24 "o.c.		
Framing (check one)	Wall:		15%
		✓	12%
			9% (48"o.c.)
	Floor/Ceilin		10%
			7% (24"o.c.)
			4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA		

List of Construction Components — **R-Value**

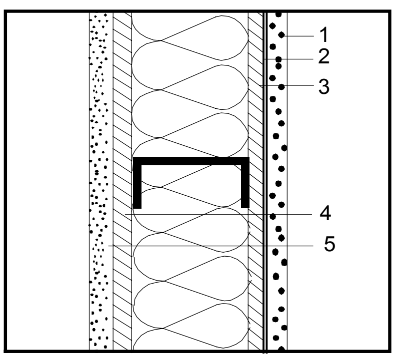
	Component	Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.180	0.180
2.	Building paper (felt)	0.060	0.060
3.	R-19 fiberglass insulation	19.000	-----
4.	2x6 in fir framing	-----	5.445
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	20.540	6.985
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\underset{1\div R_c}{1/20.540}\right) \times \left(\underset{1-(\text{Fr.}\%\div 100)}{1-12/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/6.985}\right) \times \left(\underset{\text{Fr.}\%\div 100}{12/100}\right)\right] = \boxed{0.060}\ \textbf{Total U-factor}$$

$$\underset{1\div\text{Total U-factor}}{1/0.060} = 16.666\ \textbf{Total R-Value}$$

Reference Name: **W.19.S2x6.24**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
	✓	Wall
		Ceiling/Roof
Framing Material:	Metal	
Framing Spacing:	24 "o.c.	
Framing Size:	Actual Depth	6.000
	Actual Width	1.625
Cavity Insulation:	R-value	19.00
	Knock-out (%)	15.00
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components — **R-Value**

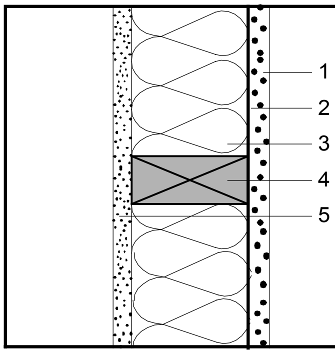
	Component	R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.180
2.	Building paper (felt)	0.060
3.	0.75 in polyisocyanurate	5.280
4.	0.50 in polyisocyanurate	3.520
5.	0.50 in gypsum board	0.450
6.		
7.		
	Inside Surface Air Film	0.680

Calculation:

From EZFRAME = $\boxed{0.060}$ **Total U-factor**

$$\underset{1\div\text{Total U-factor}}{1/0.060} = 16.750\ \textbf{Total R-Value}$$

Reference Name: **W.21.2x6.16**



Sketch of Construction Assembly

Assembly Type: (check one)
- ___ Floor
- ✓ Wall
- ___ Ceiling/Roof

Framing Material: **Wood**

Framing Size: 2 × 6

Framing Spacing: 16 "o.c.

Framing (check one)

Wall: ✓ 15%; ___ 12%; ___ 9% (48"o.c.)

Floor/Ceilin ___ 10%; ___ 7% (24"o.c.); ___ 4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components — **R-Value**

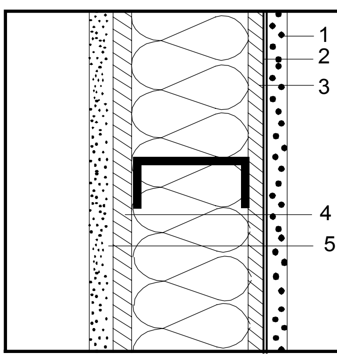
	List of Construction Components	Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.180	0.180
2.	Building paper (felt)	0.060	0.060
3.	R-21 fiberglass insulation	21.000	-----
4.	2x6 in fir framing	-----	5.445
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	22.540	6.985
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\underset{1\div R_c}{1/22.540}\right) \times \left(\underset{1-(\text{Fr.\%}\div 100)}{1-15/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/6.985}\right) \times \left(\underset{\text{Fr.\%}\div 100}{15/100}\right)\right] = \boxed{0.059}\ \textbf{Total U-factor}$$

$$\underset{1\div \text{Total U-factor}}{1/0.059} = 16.949\ \textbf{Total R-Value}$$

Reference Name: **W.21.S2x6.16**



Sketch of Construction Assembly

Assembly Type: (check one)
- ___ Floor
- ✓ Wall
- ___ Ceiling/Roof

Framing Material: **Metal**

Framing Spacing: 16 "o.c.

Framing Size: Actual Depth 6.000; Actual Width 1.625

Cavity Insulation: R-value 21.00; Knock-out (%) 15.00; Web 0.060

Insulation Tape R- Interior Flange ___; Exterior ___

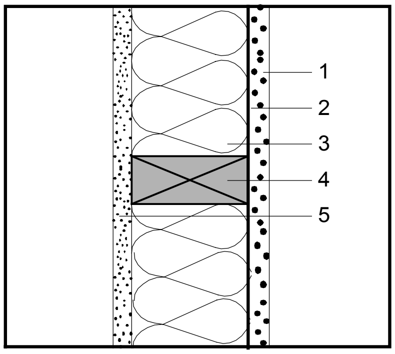
	List of Construction Components	R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.180
2.	Building paper (felt)	0.060
3.	1.0 in polyisocyanurate	7.040
4.	0.5 in polyisocyanurate	3.520
5.	0.50 in gypsum or plaster board	0.450
6.		
7.		
	Inside Surface Air Film	0.680

Calculation:

From EZFRAME = $\boxed{0.057}$ **Total U-factor**

$$\underset{1\div \text{Total U-factor}}{1/0.057} = 17.440\ \textbf{Total R-Value}$$

Reference Name: **W.21.2x6.24**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
	✓	Wall
		Ceiling/Roof
Framing Material:	**Wood**	
Framing Size:	2 × 6	
Framing Spacing:	24 "o.c.	
Framing (check one)	Wall:	15%
	✓	12%
		9% (48"o.c.)
	Floor/Ceilin	10%
		7% (24"o.c.)
		4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA	

List of Construction Components

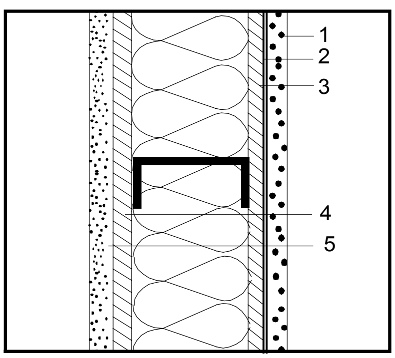
		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.180	0.180
2.	Building paper (felt)	0.060	0.060
3.	R-21 fiberglass insulation	21.000	-----
4.	2x6 in fir framing	-----	5.445
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	22.540	6.985
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\underset{1\div R_c}{1/22.540}\right) \times \left(\underset{1-(\text{Fr.}\%\div 100)}{1-12/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/6.985}\right) \times \left(\underset{\text{Fr.}\%\div 100}{12/100}\right)\right] = \boxed{0.056}\ \textbf{Total U-factor}$$

$$\underset{1\div\text{Total U-factor}}{1/0.056} = \underset{\textbf{Total R-Value}}{17.857}$$

Reference Name: **W.21.S2x6.24**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
	✓	Wall
		Ceiling/Roof
Framing Material:	**Metal**	
Framing Spacing:	24 "o.c.	
Framing Size:	Actual Depth	6.000
	Actual Width	1.625
Cavity Insulation:	R-value	21.000
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components

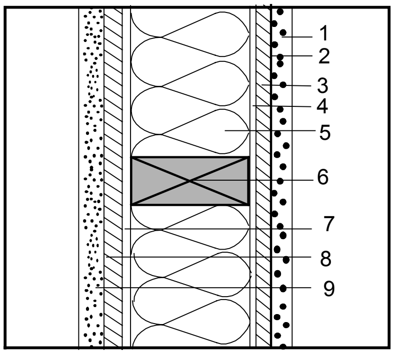
		R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.180
2.	Building paper (felt)	0.060
3.	1.0 in polyisocyanurate	7.040
4.	0.5 in polyisocyanurate	3.520
5.	0.50 in gypsum or plaster board	0.450
6.		
7.		
	Inside Surface Air Film	0.680

Calculation:

From EZFRAME = $\boxed{0.053}$ **Total U-factor**

$$\underset{1\div\text{Total U-factor}}{1/0.053} = \underset{\textbf{Total R-Value}}{18.720}$$

Reference Name: **WP.22.2x6.48**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor	
	✓	Wall	
		Ceiling/Roof	
Framing Material:	**Wood**		
Framing Size:	2 × 6		
Framing Spacing:	48 "o.c.		
Framing (check one)	Wall:		15%
			12%
		✓	9% (48"o.c.)
	Floor/Ceilin		10%
			7% (24"o.c.)
			4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA		

List of Construction Components

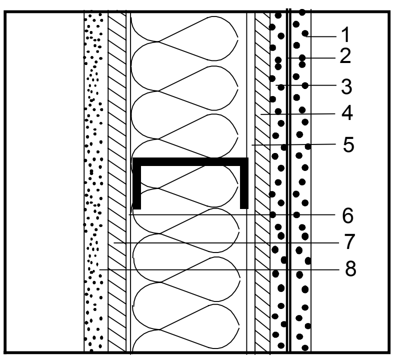
		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.180	0.180
2.	Building paper (felt)	0.060	0.060
3.	0.375 in plywood	0.470	0.470
4.	0.875 in Furring Channel	0.800	0.800
5.	R-21.656 EPS foam insulation	21.656	-----
6.	2x6 in fir framing	-----	5.445
7.	0.875 in Furring Channel	0.800	0.800
8.	0.375 in plywood	0.470	0.470
9.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	25.736	9.525
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\underset{1\div R_c}{1/25.736}\right) \times \left(\underset{1-(\text{Fr.\%}\div 100)}{1-9/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/9.525}\right) \times \left(\underset{\text{Fr.\%}\div 100}{9/100}\right)\right] = \underset{\textbf{Total U-factor}}{\boxed{0.049}}$$

$$\underset{1\div\text{Total U-factor}}{1/0.049} = \underset{\textbf{Total R-Value}}{20.408}$$

Reference Name: **WP.22.S2x6.48**



Sketch of Construction Assembly

Assembly Type: (check one)			Floor
		✓	Wall
			Ceiling/Roof
Framing Material:		**Metal**	
Framing Spacing:		48 "o.c.	
Framing Size:	Actual Depth	6.000	
	Actual Width	1.625	
Cavity Insulation:	R-value	21.700	
	Knock-out (%)	15.00	
	Web	0.060	
Insulation Tape R-	Interior Flange		
	Exterior		

List of Construction Components

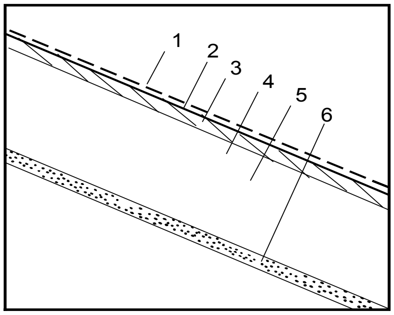
		R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.180
2.	Building paper (felt)	0.060
3.	1.50 in polyisocyanurate	10.560
4.	0.50 in plywood	0.630
5.	0.875 in Furring channel	0.800
6.	0.875 in Furring channel	0.800
7.	0.50 in plywood	0.630
8.	0.50 in gypsum or plaster board	0.450
	Inside Surface Air Film	0.680

Calculation:

From EZFRAME $= \underset{\textbf{Total U-factor}}{\boxed{0.044}}$

$$\underset{1\div\text{Total U-factor}}{1/0.044} = \underset{\textbf{Total R-Value}}{22.83}$$

Reference Name: **R.0.2x6.16**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor	
		Wall	
	✓	Ceiling/Roof	
Framing Material:	**Wood**		
Framing Size:	2 × 6		
Framing Spacing:	16 "o.c.		
Framing (check one)	Wall:		15%
			12%
			9% (48"o.c.)
	Floor/Ceilin	✓	10%
			7% (24"o.c.)
			4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA		

List of Construction Components

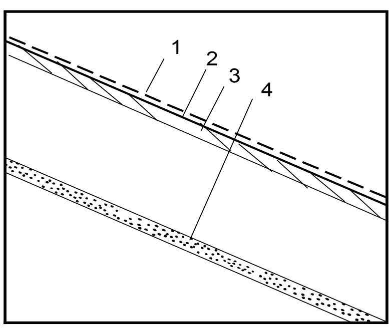
		R-Value	
		Cavity (R_c)	**Frame (R_f)**
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.630	0.630
4.	3.5 in & greater air space; heat flow up	0.800	-----
5.	2x6 in fir framing	-----	5.445
6.	0.50 in gypsum or plaster board	0.450	0.450
7.			
	Inside Surface Air Film	0.620	0.620
	Total Unadjusted R-Values:	3.170	7.815
		R_c	**R_f**

Framing Adjustment Calculation:

$$\left[\left(\underset{1\div R_c}{\underline{1/3.170}}\right) \times \left(\underset{1\text{-(Fr.\% }\div 100)}{\underline{1\text{-}10/100}}\right)\right] + \left[\left(\underset{1\div R_f}{\underline{1/7.815}}\right) \times \left(\underset{\text{Fr.\% }\div 100}{\underline{10/100}}\right)\right] = \underset{\textbf{Total U-factor}}{\boxed{\mathbf{0.297}}}$$

$$\underset{1\div\text{Total U-factor}}{\underline{1/0.297}} = \underset{\textbf{Total R-Value}}{\underline{3.367}}$$

Reference Name: **R.0.S2X6.16**



Sketch of Construction Assembly

Assembly Type: (check one)			Floor
			Wall
		✓	Ceiling/Roof
Framing Material:	**Metal**		
Framing Spacing:	16 "o.c.		
Framing Size:	Actual Depth	6.000	
	Actual Width	1.625	
Cavity Insulation:	R-value	0.800	
	Knock-out (%)	15.000	
	Web	0.060	
Insulation Tape R-	Interior Flange		
	Exterior		

List of Construction Components

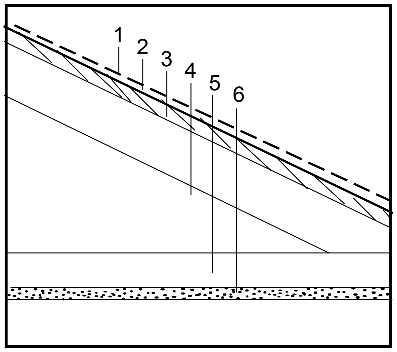
		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle roofing	0.440
2.	Building paper (felt)	0.060
3.	0.50 in plywood	0.630
4.	0.50 in gypsum or plaster board	0.450
5.		
6.		
7.		
	Inside Surface Air Film	0.620

Calculation:

From EZFRAME = $\underset{\textbf{Total U-factor}}{\boxed{\mathbf{0.323}}}$

$$\underset{1\div\text{Total U-factor}}{\underline{1/0.323}} = \underset{\textbf{Total R-Value}}{\underline{3.090}}$$

Reference Name: **R.0.2x4.24**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor	
		Wall	
	✓	Ceiling/Roof	
Framing Material:	**Wood**		
Framing Size:	2 × 4		
Framing Spacing:	24 "o.c.		
Framing (check one)	Wall:		15%
			12%
			9% (48"o.c.)
	Floor/Ceilin		10%
		✓	7% (24"o.c.)
			4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA		

List of Construction Components

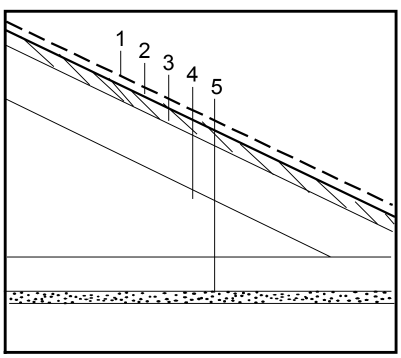
		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.630	0.630
4.	3.5" & greater air space; heat sidways	0.800	0.800
5.	2x4 in fir framing	-----	3.465
6.	0.50 in gypsum or plaster board	0.450	0.450
7.			
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	3.160	6.625
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\underset{1\div R_c}{1/3.160}\right) \times \left(\underset{1-(\text{Fr.}\% \div 100)}{1-7/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/6.625}\right) \times \left(\underset{\text{Fr.}\% \div 100}{7/100}\right)\right] = \underset{\textbf{Total U-factor}}{\boxed{0.305}}$$

$$\frac{1/0.305}{1\div\text{Total U-factor}} = \underset{\textbf{Total R-Value}}{3.279}$$

Reference Name: **R.0.S2X4.24**



Sketch of Construction Assembly

Assembly Type: (check one)			Floor
			Wall
		✓	Ceiling/Roof
Framing Material:	**Metal**		
Framing Spacing:	24 "o.c.		
Framing Size:	Actual Depth	3.625	
	Actual Width	1.625	
Cavity Insulation:	R-value	0.800	
	Knock-out (%)	15.00	
	Web	0.060	
Insulation Tape R-	Interior Flange		
	Exterior		

List of Construction Components

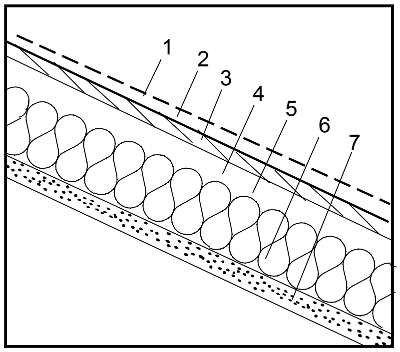
		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle roofing	0.440
2.	Building paper (felt)	0.060
3.	0.50 in plywood	0.630
4.	3.5" & greater air space; heat sidways	0.800
5.	0.50 in gypsum or plaster board	0.450
6.		
7.		
	Inside Surface Air Film	0.610

Calculation:

From EZFRAME = $\underset{\textbf{Total U-factor}}{\boxed{0.316}}$

$$\frac{1/0.316}{1\div\text{Total U-factor}} = \underset{\textbf{Total R-Value}}{3.160}$$

Reference Name: **R.11.2x6.16**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
		Wall
	✓	Ceiling/Roof
Framing Material:	**Wood**	
Framing Size:	2 × 6	
Framing Spacing:	16 "o.c.	
Framing (check one)	Wall:	15%
		12%
		9% (48"o.c.)
	Floor/Ceilin ✓	10%
		7% (24"o.c.)
		4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA	

List of Construction Components | **R-Value**

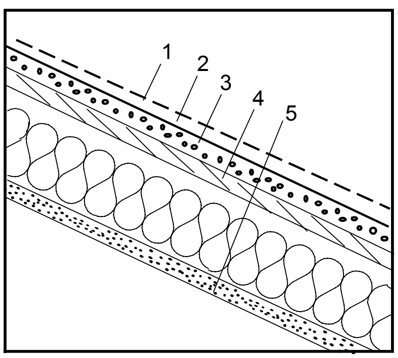
	Component	Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.630	0.630
4.	2.0 in air space; heat flow up	0.780	-----
5.	2x6 in fir framing	-----	5.445
6.	R-11 fiberglass insulation	11.000	-----
7.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.620	0.620
	Total Unadjusted R-Values:	14.150	7.815
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\underset{1 \div R_c}{1/14.150}\right) \times \left(\underset{1-(\text{Fr.}\% \div 100)}{1-10/100}\right)\right] + \left[\left(\underset{1 \div R_f}{1/7.815}\right) \times \left(\underset{\text{Fr.}\% \div 100}{10/100}\right)\right] = \underset{\textbf{Total U-factor}}{\boxed{0.076}}$$

$$\underset{1 \div \text{Total U-factor}}{1/0.076} = \underset{\textbf{Total R-Value}}{13.157}$$

Reference Name: **R.11.S2X6.16**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
		Wall
	✓	Ceiling/Roof
Framing Material:	**Metal**	
Framing Spacing:	16 "o.c.	
Framing Size:	Actual Depth	6.000
	Actual Width	1.625
Cavity Insulation:	R-value	11.800
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components | **R-Value**

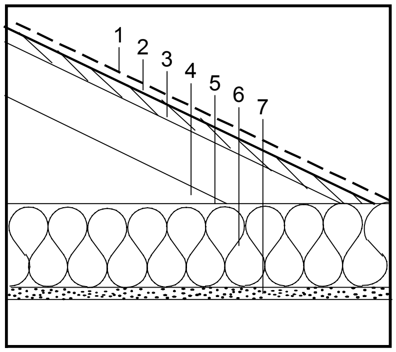
	Component	R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle	0.440
2.	Building paper (felt)	0.060
3.	0.75 in Polyisocyanurate	5.280
4.	0.625 in Plywood	0.780
5.	0.50 in gypsum or plaster board	0.450
6.		
7.		
	Inside Surface Air Film	0.620

Calculation:

From EZFRAME = $\underset{\textbf{Total U-factor}}{\boxed{0.071}}$

$$\underset{1 \div \text{Total U-factor}}{1/0.071} = \underset{\textbf{Total R-Value}}{14.060}$$

Reference Name: **R.11.2x4.24**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
		Wall
	✓	Ceiling/Roof
Framing Material:	**Wood**	
Framing Size:	2 × 4	
Framing Spacing:	24 “o.c.	
Framing (check one)	Wall:	15%
		12%
		9% (48”o.c.)
	Floor/Ceilin	10%
	✓	7% (24”o.c.)
		4% (48”o.c.)
Wall Weight / sf: (Packages only)	NA	

List of Construction Components

	List of Construction Components	R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.630	0.630
4.	3.50 in & greater air space; heat flow up	0.800	0.800
5.	R-11 fiberglass insulation	11.000	-----
6.	2x4 in fir framing	-----	3.465
7.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	14.160	6.625
		R_c	R_f

Framing Adjustment Calculation:

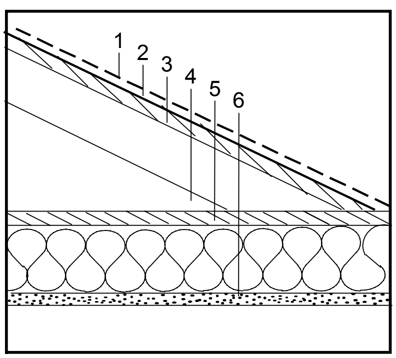
$$\left[\left(\underset{1\div R_c}{1/14.160}\right) \times \left(\underset{1-(\text{Fr.}\%\div 100)}{1-7/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/6.625}\right) \times \left(\underset{\text{Fr.}\%\div 100}{7/100}\right)\right] = \boxed{0.076}$$

Total U-factor

$$\underset{1\div \text{Total U-factor}}{1/0.076} = 13.157$$

Total R-Value

Reference Name: **R.11.S2X4.24**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
		Wall
	✓	Ceiling/Roof
Framing Material:	**Metal**	
Framing Spacing:	24 “o.c.	
Framing Size:	Actual Depth	3.625
	Actual Width	1.625
Cavity Insulation:	R-value	11.000
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components

	List of Construction Components	R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle roofing	0.440
2.	Building paper (felt)	0.060
3.	0.50 in plywood	0.630
4.	3.50 in & greater air space; heat flow up	0.800
5.	0.75 in Polyisocyanurate	5.280
6.	0.50 in gypsum or plaster board	0.450
7.		
	Inside Surface Air Film	0.610

Calculation:

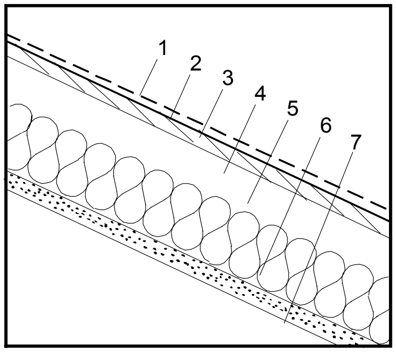
From EZFRAME = $\boxed{0.069}$

Total U-factor

$$\underset{1\div \text{Total U-factor}}{1/0.069} = 14.500$$

Total R-Value

Reference Name: **R.13.2x6.16**



Sketch of Construction Assembly

Assembly Type: (check one)

____	Floor
____	Wall
✓	Ceiling/Roof

Framing Material: **Wood**
Framing Size: 2 × 6
Framing Spacing: 16 "o.c.
Framing (check one)

Wall:	____	15%
	____	12%
	____	9% (48"o.c.)
Floor/Ceilin	✓	10%
	____	7% (24"o.c.)
	____	4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components

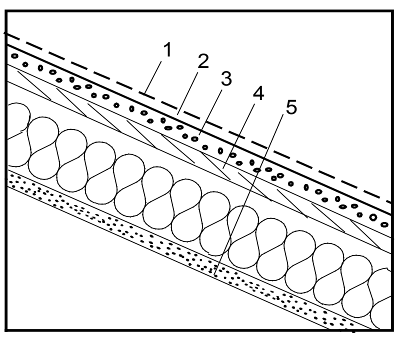
		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.630	0.630
4.	2.0 in air space; heat flow up	0.780	-----
5.	2x6 in fir framing	-----	5.445
6.	R-13 fiberglass insulation	13.000	-----
7.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.620	0.620
	Total Unadjusted R-Values:	16.150	7.815
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\underset{1\div R_c}{1/16.150}\right) \times \left(\underset{1-(\text{Fr.\%}\div 100)}{1-10/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/7.815}\right) \times \left(\underset{\text{Fr.\%}\div 100}{10/100}\right)\right] = \underset{\textbf{Total U-factor}}{\boxed{0.069}}$$

$$\underset{1\div\text{Total U-factor}}{1/0.069} = \underset{\textbf{Total R-Value}}{14.493}$$

Reference Name: **R.13.S2X6.16**



Sketch of Construction Assembly

Assembly Type: (check one)

____	Floor
____	Wall
✓	Ceiling/Roof

Framing Material: **Metal**
Framing Spacing: 16 "o.c.

Framing Size:	Actual Depth	6.000
	Actual Width	1.625
Cavity Insulation:	R-value	13.800
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components

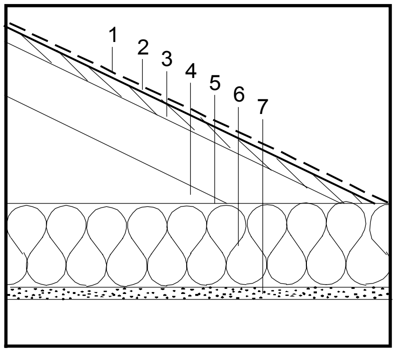
		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle roofing	0.440
2.	Building paper (felt)	0.060
3.	1.00 in polyisocyanurate	7.040
4.	0.50 in plywood	0.630
5.	0.50 in gypsum or plaster board	0.450
6.		
7.		
	Inside Surface Air Film	0.620

Calculation:

$$\text{From EZFRAME} = \underset{\textbf{Total U-factor}}{\boxed{0.062}}$$

$$\underset{1\div\text{Total U-factor}}{1/0.062} = \underset{\textbf{Total R-Value}}{16.130}$$

Reference Name: **R.13.2x4.24**



Sketch of Construction Assembly

Assembly Type:		Floor
(check one)		Wall
	✓	Ceiling/Roof
Framing Material:	**Wood**	
Framing Size:	2 × 4	
Framing Spacing:	24 "o.c.	
Framing (check one)	Wall:	15%
		12%
		9% (48"o.c.)
	Floor/Ceilin	10%
	✓	7% (24"o.c.)
		4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA	

List of Construction Components

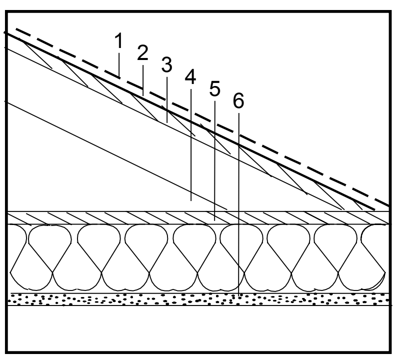
		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.630	0.630
4.	3.50 in & greater air space; heat flow up	0.800	0.800
5.	R-13 fiberglass insulation	13.000	-----
6.	2x4 in fir framing	-----	3.465
7.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	16.160	6.625
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\underset{1\div R_c}{1/16.160}\right) \times \left(\underset{1-(\text{Fr.}\% \div 100)}{1-7/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/6.625}\right) \times \left(\underset{\text{Fr.}\% \div 100}{7/100}\right)\right] = \boxed{0.068}\ \textbf{Total U-factor}$$

$$\underset{1\div\text{Total U-factor}}{1/0.068} = 14.705\ \textbf{Total R-Value}$$

Reference Name: **R.13.S2X4.24**



Sketch of Construction Assembly

Assembly Type:		Floor
(check one)		Wall
	✓	Ceiling/Roof
Framing Material:	**Metal**	
Framing Spacing:	24 "o.c.	
Framing Size:	Actual Depth	3.625
	Actual Width	1.625
Cavity Insulation:	R-value	13.000
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components

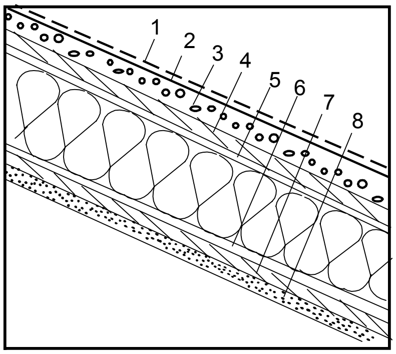
		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle roofing	0.440
2.	Building paper (felt)	0.060
3.	0.50 in plywood	0.630
4.	3.50 in & greater air space; heat flow up	0.800
5.	0.75 in Polyisocyanurate	5.280
6.	0.50 in gypsum or plaster board	0.450
7.		
	Inside Surface Air Film	0.610

Calculation:

From EZFRAME = $\boxed{0.066}$ **Total U-factor**

$$\underset{1\div\text{Total U-factor}}{1/0.066} = 15.100\ \textbf{Total R-Value}$$

Reference Name: **RP.14.2x4.48**



Sketch of Construction Assembly

Assembly Type:	____	Floor
(check one)	____	Wall
	✓	Ceiling/Roof
Framing Material:	**Wood**	
Framing Size:	2 × 4	
Framing Spacing:	48 "o.c.	
Framing (check one)	Wall: ____	15%
	____	12%
	____	9% (48"o.c.)
	Floor/Ceilin ____	10%
	____	7% (24"o.c.)
	✓	4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA	

List of Construction Components

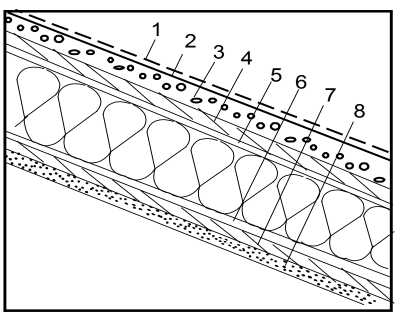
		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.375 in plywood	0.470	0.470
4.	7/8 in furring channel	0.800	0.800
5.	2x4 in fir framing	-----	3.465
6.	3 5/8 in EPS foam insulation @3.85/inch	13.956	-----
7.	7/8 in furring channel	0.800	0.800
8.	0.375 in plywood	0.470	0.470
9.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.620	0.620
	Total Unadjusted R-Values:	18.236	7.745
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\frac{1/18.236}{1\div R_c}\right) \times \left(\frac{1-4/100}{1-(\text{Fr.}\% \div 100)}\right)\right] + \left[\left(\frac{1/7.745}{1\div R_f}\right) \times \left(\frac{4/100}{\text{Fr.}\% \div 100}\right)\right] = \boxed{0.058}\ \textbf{Total U-factor}$$

$$\frac{1/0.058}{1\div \text{Total U-factor}} = 17.241\ \textbf{Total R-Value}$$

Reference Name: **RP.14.S2x4.48**



Sketch of Construction Assembly

Assembly Type:	____	Floor
(check one)	____	Wall
	✓	Ceiling/Roof
Framing Material:	**Metal**	
Framing Spacing:	48 "o.c.	
Framing Size:	Actual Depth	3.625
	Actual Width	1.625
Cavity Insulation:	R-value	14.000
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components

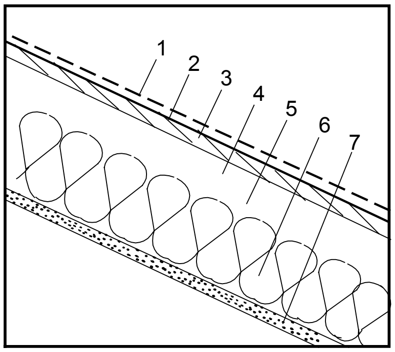
		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle roofing	0.440
2.	Building paper	0.060
3.	0.75 in polyisocyanurate	5.280
4.	3/8 in plywood	0.470
5.	7/8 in furring channel	0.800
6.	7/8 in furring channel	0.800
7.	3/8 in plywood	0.470
8.	1/2 in gypsum or plaster board	0.450
	Inside Surface Air Film	0.620

Calculation:

From EZFRAME = $\boxed{0.055}$ **Total U-factor**

$$\frac{1/0.055}{1\div \text{Total U-factor}} = 18.130\ \textbf{Total R-Value}$$

Reference Name: **R.19.2x8.16**



Sketch of Construction Assembly

Assembly Type: (check one)

	Floor
	Wall
✓	Ceiling/Roof

Framing Material: Wood
Framing Size: 2 × 8
Framing Spacing: 16 "o.c.
Framing (check one)

Wall:		15%
		12%
		9% (48"o.c.)
Floor/Ceilin	✓	10%
		7% (24"o.c.)
		4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components	**R-Value** Cavity (R_c)	Frame (R_f)
Outside Surface Air Film	0.170	0.170
1. Asphalt shingle roofing	0.440	0.440
2. Building paper (felt)	0.060	0.060
3. 0.50 in plywood	0.630	0.630
4. 1.0 in air space; heat flow up	0.760	-----
5. 2x8 in fir framing	-----	7.178
6. R-19 fiberglass insulation	19.000	-----
7. 0.50 in gypsum or plaster board	0.450	0.450
Inside Surface Air Film	0.620	0.620
Total Unadjusted R-Values:	22.130	9.548
	R_c	R_f

Framing Adjustment Calculation:

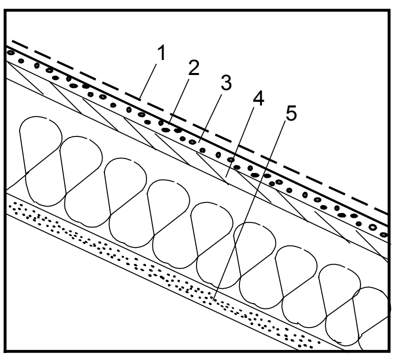
$$\left[\left(\underset{1\div R_c}{1/22.130}\right) \times \left(\underset{1\text{-}(\text{Fr.}\%\div100)}{1\text{-}10/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/9.548}\right) \times \left(\underset{\text{Fr.}\%\div100}{10/100}\right)\right] = \boxed{0.051}$$

Total U-factor

$$\underset{1\div\text{Total U-factor}}{1/0.051} = 19.608$$

Total R-Value

Reference Name: **R.19.S2x8.16**



Sketch of Construction Assembly

Assembly Type: (check one)

	Floor
	Wall
✓	Ceiling/Roof

Framing Material: Metal
Framing Spacing: 16 "o.c.

Framing Size:	Actual Depth	8.000
	Actual Width	1.625
Cavity Insulation:	R-value	19.800
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components	**R-Value**
Outside Surface Air Film	0.170
1. Asphalt shingle roofing	0.440
2. Building Paper	0.060
3. 1.25 in Polyisocyanurate	8.800
4. 0.5 in plywood	0.630
5. 0.50 in Gypsum board	0.450
6.	
7.	
Inside Surface Air Film	0.620

Calculation:

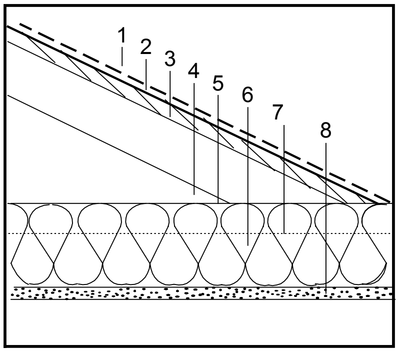
From EZFRAME = $\boxed{0.051}$

Total U-factor

$$\underset{1\div\text{Total U-factor}}{1/0.051} = 19.760$$

Total R-Value

Reference Name: **R.19.2x4.24**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
		Wall
	✓	Ceiling/Roof
Framing Material:	**Wood**	
Framing Size:	2 × 4	
Framing Spacing:	24 "o.c.	
Framing (check one)	Wall:	15%
		12%
		9% (48"o.c.)
	Floor/Ceilin	10%
	✓	7% (24"o.c.)
		4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA	

List of Construction Components

	List of Construction Components	R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.630	0.630
4.	3.50 in & greater air space; heat flow up	0.800	0.800
5.	R-8 fiberglass insulation	8.000	8.000
6.	R-11 fiberglass insulation	11.000	-----
7.	2x4 in fir framing	------	3.465
8.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	22.160	14.625
		R_c	R_f

Framing Adjustment Calculation:

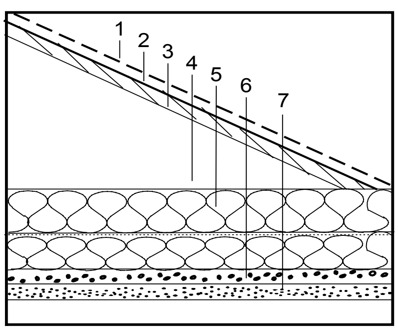
$$\left[\left(\underset{1 \div R_c}{1/22.160}\right) \times \left(\underset{1-(\text{Fr.\%} \div 100)}{1\text{-}7/100}\right)\right] + \left[\left(\underset{1 \div R_f}{1/14.625}\right) \times \left(\underset{\text{Fr.\%} \div 100}{7/100}\right)\right] = \boxed{0.047}$$

Total U-factor

$$\underset{1 \div \text{Total U-factor}}{1/0.047} = 21.277$$

Total R-Value

Reference Name: **R.19.S2x4.24**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
		Wall
	✓	Ceiling/Roof
Framing Material:	**Metal**	
Framing Spacing:	24 "o.c.	
Framing Size:	Actual Depth	3.625
	Actual Width	1.625
Cavity Insulation:	R-value	11.000
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components

	List of Construction Components	R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle roofing	0.440
2.	Building paper (felt)	0.060
3.	0.625 in Plywood	0.780
4.	3.5 in Air, Ceiling	0.800
5.	R-8 fiberglass insulation	8.000
6.	0.75 in polyisocyanurate	5.280
7.	0.50 in Gypsum board	0.450
	Inside Surface Air Film	0.610

Calculation:

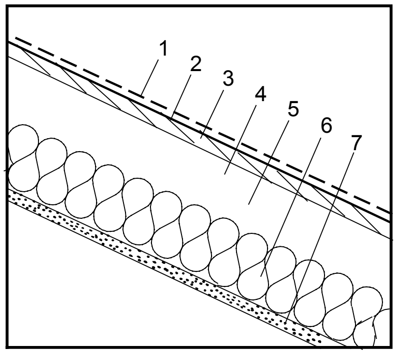
From EZFRAME = $\boxed{0.044}$

Total U-factor

$$\underset{1 \div \text{Total U-factor}}{1/0.044} = 22.670$$

Total R-Value

Reference Name: **R.22.2x10.16**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
		Wall
	✓	Ceiling/Roof
Framing Material:	Wood	
Framing Size:	2 × 10	
Framing Spacing:	16 "o.c.	
Framing (check one)	Wall:	15%
		12%
		9% (48"o.c.)
	Floor/Ceilin ✓	10%
		7% (24"o.c.)
		4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA	

List of Construction Components

		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.630	0.630
4.	3.5" & greater air space; heat sideways	0.620	0.620
5.	2x10 in fir framing	-----	9.158
6.	R-22 fiberglass insulation	22.000	-----
7.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.620	0.620
	Total Unadjusted R-Values:	24.990 (R_c)	12.148 (R_f)

Framing Adjustment Calculation:

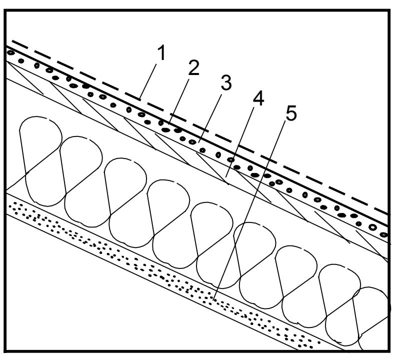
$$\left[\left(\underset{1\div R_c}{1/24.990}\right) \times \left(\underset{1-(\text{Fr.}\%\div 100)}{1-10/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/12.148}\right) \times \left(\underset{\text{Fr.}\%\div 100}{10/100}\right)\right] = \boxed{0.044}$$

Total U-factor

$$\underset{1\div\text{Total U-factor}}{1/0.044} = 22.727$$

Total R-Value

Reference Name: **R.22.S2x10.16**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
		Wall
	✓	Ceiling/Roof
Framing Material:	Metal	
Framing Spacing:	16 "o.c.	
Framing Size:	Actual Depth	10.000
	Actual Width	1.625
Cavity Insulation:	R-value	22.800
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components

		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle roofing	0.440
2.	Building paper (felt)	0.060
3.	1.50 in polyisocyanurate	10.560
4.	0.50 in Plywood	0.630
5.	0.50 in gypsum or plaster board	0.450
6.		
7.		
	Inside Surface Air Film	0.620

Calculation:

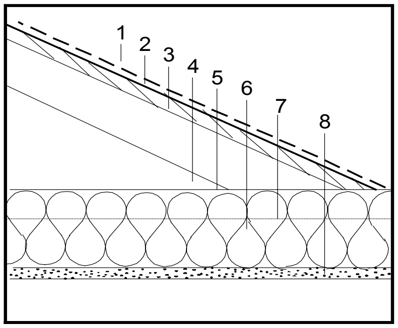
From EZFRAME = $\boxed{0.044}$

Total U-factor

$$\underset{1\div\text{Total U-factor}}{1/0.044} = 22.660$$

Total R-Value

Reference Name: **R.22.2x4.24**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
		Wall
	✓	Ceiling/Roof
Framing Material:	**Wood**	
Framing Size:	2 × 4	
Framing Spacing:	24 "o.c.	
Framing (check one)	Wall:	15%
		12%
		9% (48"o.c.)
	Floor/Ceilin	10%
	✓	7% (24"o.c.)
		4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA	

List of Construction Components

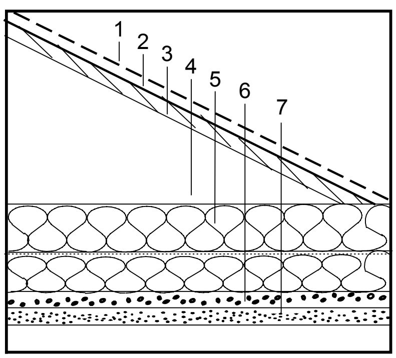
	List of Construction Components	R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.630	0.630
4.	3.50 in & greater air space	0.800	0.800
5.	R-11 fiberglass insulation	11.000	11.000
6.	R-11 fiberglass insulation	11.000	-----
7.	2x4 in fir framing	-----	3.465
8.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	25.160	17.625
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\underset{1\div R_c}{1/25.160}\right) \times \left(\underset{1-(\text{Fr.}\% \div 100)}{1-7/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/17.625}\right) \times \left(\underset{\text{Fr.}\% \div 100}{7/100}\right)\right] = \boxed{0.041}\ \textbf{Total U-factor}$$

$$\underset{1\div\text{Total U-factor}}{1/0.041} = \underset{\textbf{Total R-Value}}{24.390}$$

Reference Name: **R.22.S2x4.24**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
		Wall
	✓	Ceiling/Roof
Framing Material:	**Metal**	
Framing Spacing:	24 "o.c.	
Framing Size:	Actual Depth	3.625
	Actual Width	1.625
Cavity Insulation:	R-value	11.000
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components

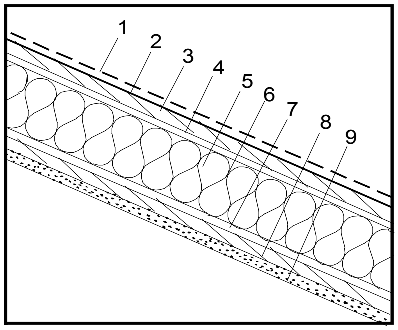
	List of Construction Components	R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle roofing	0.440
2.	Building paper (felt)	0.060
3.	0.50 in plywood	0.630
4.	3.50 in & greater air space	0.800
5.	R-11 fiberglass insulation	11.000
6.	0.75 in Polyisocyanurate	5.280
7.	0.50 in Gypsum Board	0.450
	Inside Surface Air Film	0.610

Calculation:

From EZFRAME = $\boxed{0.039}$ **Total U-factor**

$$\underset{1\div\text{Total U-factor}}{1/0.039} = \underset{\textbf{Total R-Value}}{25.500}$$

Reference Name: **RP.22.2x6.48**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
		Wall
	✓	Ceiling/Roof
Framing Material:	Wood	
Framing Size:	2 × 6	
Framing Spacing:	48 "o.c.	
Framing (check one)	Wall:	15%
		12%
		9% (48"o.c.)
	Floor/Ceilin	10%
		7% (24"o.c.)
	✓	4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA	

List of Construction Components

		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.375 in plywood	0.470	0.470
4.	0.875 in furring channel	0.800	0.800
5.	5 5/8 in EPS foam insulation @ R-3.85/inch	21.656	-----
6.	2x6 in fir framing	-----	5.445
7.	0.875 in furring channel	0.800	0.800
8.	0.375 in plywood	0.470	0.470
9.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.620	0.620
	Total Unadjusted R-Values:	25.936 (R_c)	9.725 (R_f)

Framing Adjustment Calculation:

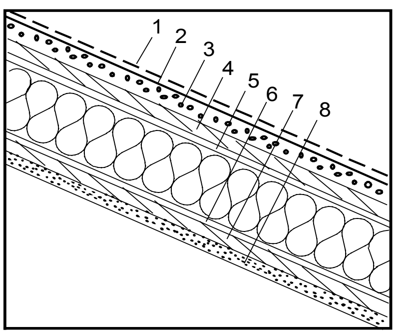
$$\left[\left(\underset{1\div R_c}{1/25.936}\right) \times \left(\underset{1-(Fr.\%\div 100)}{1-4/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/9.725}\right) \times \left(\underset{Fr.\%\div 100}{4/100}\right)\right] = \boxed{0.041}$$

Total U-factor

$$\underset{1\div \text{Total U-factor}}{1/0.041} = 24.390$$

Total R-Value

Reference Name: **RP.22.S2x6.48**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
		Wall
	✓	Ceiling/Roof
Framing Material:	Metal	
Framing Spacing:	48 "o.c.	
Framing Size:	Actual Depth	6.000
	Actual Width	1.625
Cavity Insulation:	R-value	22.000
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components

		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle roofing	0.440
2.	Building paper (felt)	0.060
3.	1.00 in polyisocyanurate	7.040
4.	0.375 in Plywood	0.470
5.	0.875 in furring channel	0.800
6.	0.875 in furring channel	0.800
7.	0.375 in Plywood	0.470
8.	0.50 in gypsum or plaster board	0.450
	Inside Surface Air Film	0.620

Calculation:

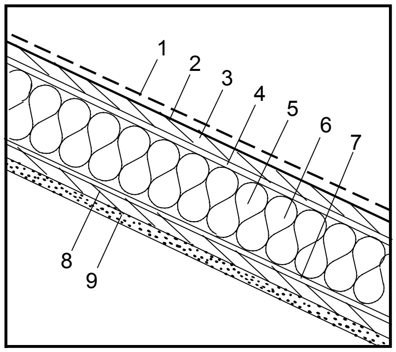
From EZFRAME = $\boxed{0.039}$

Total U-factor

$$\underset{1\div \text{Total U-factor}}{1/0.039} = 25.460$$

Total R-Value

Reference Name: RP.28.2x8.48



Sketch of Construction Assembly

Assembly Type: (check one)

	Floor
	Wall
✓	Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 8

Framing Spacing: 48 "o.c.

Framing (check one)

Wall:		15%
		12%
		9% (48"o.c.)
Floor/Ceilin		10%
		7% (24"o.c.)
	✓	4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components

	List of Construction Components	R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.375 in plywood	0.470	0.470
4.	0.875 in furring channel	0.800	0.800
5.	7 3/8 in EPS foam insulation @ R-3.85/in	28.394	-----
6.	2x8 in fir framing	-----	7.178
7.	0.875 in furring channel	0.800	0.800
8.	0.375 in plywood	0.470	0.470
9.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.620	0.620
	Total Unadjusted R-Values:	32.674	11.458
		R_c	R_f

Framing Adjustment Calculation:

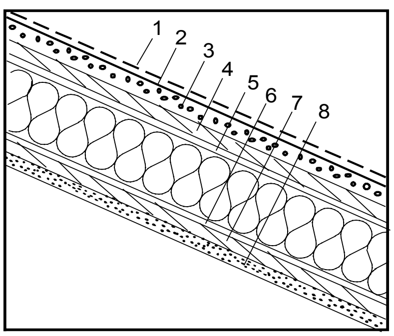
$$\left[\left(\frac{1/32.674}{1\div R_c}\right) \times \left(\frac{1-4/100}{1-(\text{Fr.}\% \div 100)}\right)\right] + \left[\left(\frac{1/11.458}{1\div R_f}\right) \times \left(\frac{4/100}{\text{Fr.}\% \div 100}\right)\right] = \boxed{0.033}$$

Total U-factor

$$\frac{1/0.033}{1\div\text{Total U-factor}} = 30.303$$

Total R-Value

Reference Name: RP.28.S2x8.48



Sketch of Construction Assembly

Assembly Type: (check one)

	Floor
	Wall
✓	Ceiling/Roof

Framing Material: Metal

Framing Spacing: 48 "o.c.

Framing Size:	Actual Depth	8.000
	Actual Width	1.625
Cavity Insulation:	R-value	28.394
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components

	List of Construction Components	R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle roofing	0.440
2.	Building paper (felt)	0.060
3.	1.75 in polyisocyanurate	12.320
4.	0.375 in Plywood	0.470
5.	0.875 in furring channel	0.800
6.	0.875 in furring channel	0.800
7.	0.375 in Plywood	0.470
8.	0.50 in gypsum or plaster board	0.450
	Inside Surface Air Film	0.620

Calculation:

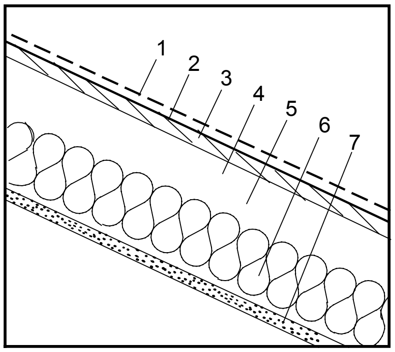
From EZFRAME = $\boxed{0.031}$

Total U-factor

$$\frac{1/0.031}{1\div\text{Total U-factor}} = 31.940$$

Total R-Value

Reference Name: **R.30.2x12.16**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
		Wall
	✓	Ceiling/Roof
Framing Material:	**Wood**	
Framing Size:	2 × 12	
Framing Spacing:	16 "o.c.	
Framing (check one)	Wall:	15%
		12%
		9% (48"o.c.)
	Floor/Ceilin ✓	10%
		7% (24"o.c.)
		4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA	

List of Construction Components — **R-Value**

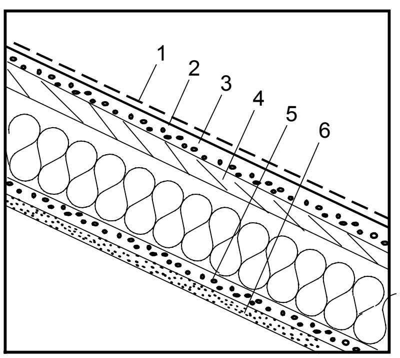
	Component	Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.630	0.630
4.	1.75 in air space; heat fow up	0.780	-----
5.	2x12 in fir framing	-----	11.138
6.	R-30 fiberglass insulation	30.000	-----
7.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.620	0.620
	Total Unadjusted R-Values:	33.150	13.508
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\underset{1\div R_c}{1/33.150}\right) \times \left(\underset{1-(\text{Fr.\%}\div 100)}{1-10/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/13.508}\right) \times \left(\underset{\text{Fr.\%}\div 100}{10/100}\right)\right] = \boxed{0.035}\ \textbf{Total U-factor}$$

$$\underset{1\div\text{Total U-factor}}{1/0.035} = \underset{\textbf{Total R-Value}}{28.571}$$

Reference Name: **R.30.S2x12.16**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
		Wall
	✓	Ceiling/Roof
Framing Material:	**Metal**	
Framing Spacing:	16 "o.c.	
Framing Size:	Actual Depth	12.000
	Actual Width	1.625
Cavity Insulation:	R-value	30.800
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components — **R-Value**

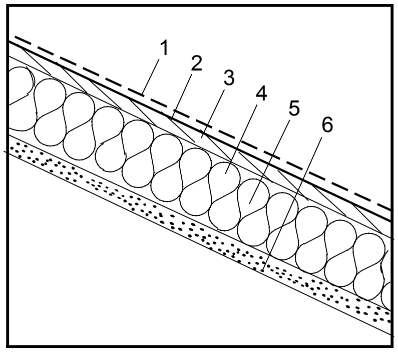
	Component	R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle roofing	0.440
2.	Building Paper	0.060
3.	1.50 in Polyisocyanurate	10.56
4.	0.50 in plywood	0.630
5.	1.00 in Polyisocyanurate	7.04
6.	0.50 in gypsum or plaster board	0.450
7.		
	Inside Surface Air Film	0.620

Calculation:

From EZFRAME = $\boxed{0.032}$ **Total U-factor**

$$\underset{1\div\text{Total U-factor}}{1/0.032} = \underset{\textbf{Total R-Value}}{31.64}$$

Reference Name: **R.30.2x10.16**



Sketch of Construction Assembly

Assembly Type: (check one)

	Floor
	Wall
✓	Ceiling/Roof

Framing Material: **Wood**
Framing Size: 2 × 10
Framing Spacing: 16 "o.c.
Framing (check one)

Wall:		15%
		12%
		9% (48"o.c.)
Floor/Ceilin	✓	10%
		7% (24"o.c.)
		4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components — **R-Value**

	List of Construction Components	Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.630	0.630
4.	2x10 in fir framing	-----	9.158
5.	R-30 fiberglass insulation (8.5'' thkns)	30.000	-----
6.	0.50 in gypsum or plaster board	0.450	0.450
7.			
	Inside Surface Air Film	0.620	0.620
	Total Unadjusted R-Values:	32.370	11.528
		R_c	R_f

Framing Adjustment Calculation:

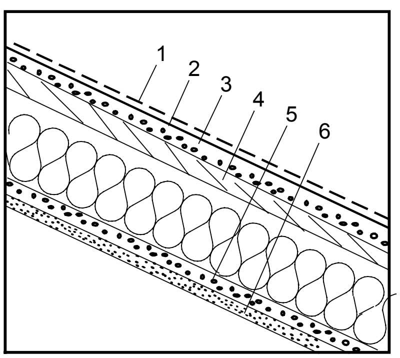
$$\left[\left(\underset{1\div R_c}{1/32.370}\right) \times \left(\underset{1\text{-}(\text{Fr.}\%\div 100)}{1\text{-}10/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/11.528}\right) \times \left(\underset{\text{Fr.}\%\div 100}{10/100}\right)\right] = \boxed{0.036}$$

Total U-factor

$$\underset{1\div\text{Total U-factor}}{1/0.036} = 27.778$$

Total R-Value

Reference Name: **R.30.S2x10.16**



Sketch of Construction Assembly

Assembly Type: (check one)

	Floor
	Wall
✓	Ceiling/Roof

Framing Material: **Metal**
Framing Spacing: 16 "o.c.

Framing Size:	Actual Depth	10.000
	Actual Width	1.625
Cavity Insulation:	R-value	30.800
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components — **R-Value**

	List of Construction Components	R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle roofing	0.440
2.	Building Paper	0.060
3.	1.50 in Polyisocyanurate	10.560
4.	0.50 in plywood	0.630
5.	0.75 in Polyisocyanurate	5.280
6.	0.50 in gypsum or plaster board	0.450
7.		
	Inside Surface Air Film	0.620

Calculation:

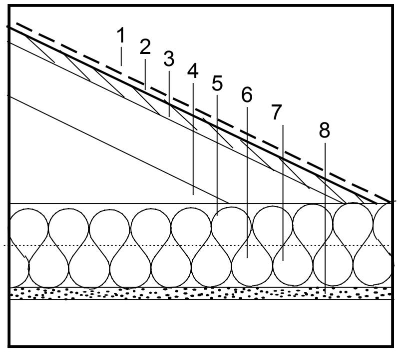
From EZFRAME = $\boxed{0.034}$

Total U-factor

$$\underset{1\div\text{Total U-factor}}{1/0.034} = 29.220$$

Total R-Value

Reference Name: **R.30.2x4.24**



Sketch of Construction Assembly

Assembly Type:		Floor	
(check one)		Wall	
	✓	Ceiling/Roof	
Framing Material:	**Wood**		
Framing Size:	2 × 4		
Framing Spacing:	24 "o.c.		
Framing	Wall:		15%
(check one)			12%
			9% (48"o.c.)
	Floor/Ceilin		10%
		✓	7% (24"o.c.)
			4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA		

List of Construction Components

	Component	R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.630	0.630
4.	3.50 in & greater air space	0.800	0.800
5.	R-19 fiberglass insulation	19.000	19.000
6.	R-11 fiberglass insulation	11.000	-----
7.	2X4 in fir framing	-----	3.465
8.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	33.160	25.625
		R_c	R_f

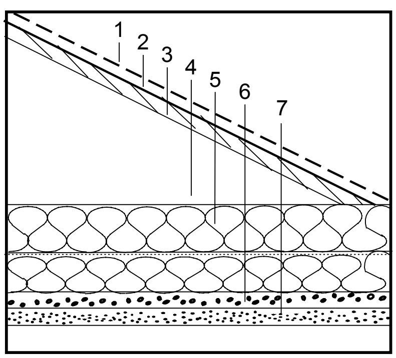
Framing Adjustment Calculation:

[(1/33.160) × (1-7/100)] + [(1/25.625) × (7/100)] = **0.031** **Total U-factor**

$1 \div R_c$ — 1-(Fr.% ÷100) — $1 \div R_f$ — Fr.% ÷100

1/0.031 (1÷Total U-factor) = 32.258 **Total R-Value**

Reference Name: **R.30.S2x4.24**



Sketch of Construction Assembly

Assembly Type:		Floor
(check one)		Wall
	✓	Ceiling/Roof
Framing Material:	**Metal**	
Framing Spacing:	24 "o.c.	
Framing Size:	Actual Depth	3.625
	Actual Width	1.625
Cavity Insulation:	R-value	11.000
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components

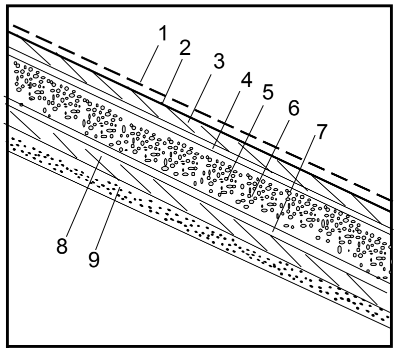
	Component	R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle roofing	0.440
2.	Building paper (felt)	0.060
3.	0.50 in plywood	0.630
4.	3.50 in & greater air space	0.800
5.	R-19 fiberglass insulation	19.000
6.	0.75 in Polyisocyanurate	5.280
7.	0.50 in Gypsum Board	0.450
	Inside Surface Air Film	0.610

Calculation:

From EZFRAME = **0.030** **Total U-factor**

1/0.030 (1÷Total U-factor) = 33.52 **Total R-Value**

Reference Name: **RP.35.2x10.48**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
		Wall
	✓	Ceiling/Roof
Framing Material:	**Wood**	
Framing Size:	2 × 10	
Framing Spacing:	48 "o.c.	
Framing (check one)	Wall:	15%
		12%
		9% (48"o.c.)
	Floor/Ceilin	10%
		7% (24"o.c.)
	✓	4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA	

List of Construction Components

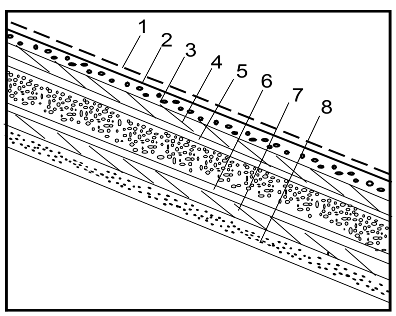
		R-Value Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.375 in plywood	0.470	0.470
4.	0.875 furring channel	0.800	0.800
5.	4 in EPS foam insulation	35.000	-----
6.	2x10 in fir framing	-----	9.158
7.	0.875 furring channel	0.800	0.800
8.	0.375 in plywood	0.470	0.470
9.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.620	0.620
	Total Unadjusted R-Values:	39.280	13.438
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\underset{1 \div R_c}{1/39.280}\right) \times \left(\underset{1-(\text{Fr.\%} \div 100)}{1-4/100}\right)\right] + \left[\left(\underset{1 \div R_f}{1/13.438}\right) \times \left(\underset{\text{Fr.\%} \div 100}{4/100}\right)\right] = \boxed{0.027} \text{ Total U-factor}$$

$$\underset{1 \div \text{Total U-factor}}{1/0.027} = 37.037 \text{ Total R-Value}$$

Reference Name: **RP.35.S2x10.48**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
		Wall
	✓	Ceiling/Roof
Framing Material:	**Metal**	
Framing Spacing:	48 "o.c.	
Framing Size:	Actual Depth	10.000
	Actual Width	1.625
Cavity Insulation:	R-value	35.000
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components

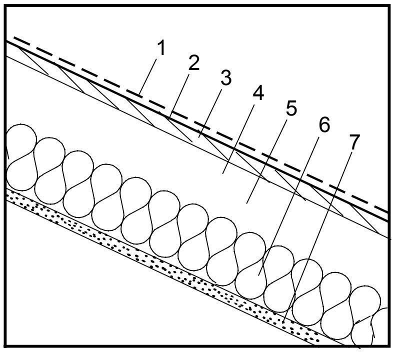
		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle roofing	0.440
2.	Building paper (felt)	0.060
3.	2.25 in polyisocyanurate	15.840
4.	0.375 in plywood	0.470
5.	0.875 in furring channel	0.800
6.	0.875 in furring channel	0.800
7.	0.375 in plywood	0.470
8.	0.50 in gypsum or plaster board	0.450
	Inside Surface Air Film	0.620

Calculation:

From EZFRAME = $\boxed{0.026}$ **Total U-factor**

$$\underset{1 \div \text{Total U-factor}}{1/0.026} = 38.44 \text{ Total R-Value}$$

Reference Name: **R.38.2x14.16**



Sketch of Construction Assembly

Assembly Type: (check one): ___ Floor; ___ Wall; ✓ Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 14

Framing Spacing: 16 "o.c.

Framing (check one):

Wall:		15%
		12%
		9% (48"o.c.)
Floor/Ceilin	✓	10%
		7% (24"o.c.)
		4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components

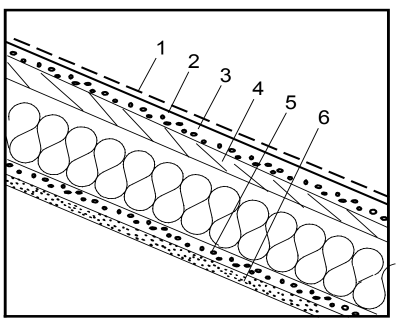
		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.630	0.630
4.	1.25 in air space; heat flow up	0.760	-----
5.	2x14 in fir framing	-----	13.118
6.	R-38 fiberglass insulation	38.000	-----
7.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.620	0.620
	Total Unadjusted R-Values:	41.130	15.488
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\underset{1\div R_c}{\underline{1/41.130}}\right) \times \left(\underset{1-(Fr.\%\div 100)}{\underline{1-10/100}}\right)\right] + \left[\left(\underset{1\div R_f}{\underline{1/15.488}}\right) \times \left(\underset{Fr.\%\div 100}{\underline{10/100}}\right)\right] = \underset{\textbf{Total U-factor}}{\boxed{0.028}}$$

$$\underset{1\div \text{Total U-factor}}{\underline{1/0.028}} = \underset{\textbf{Total R-Value}}{\underline{35.714}}$$

Reference Name: **R.38.S2x14.16**



Sketch of Construction Assembly

Assembly Type: (check one): ___ Floor; ___ Wall; ✓ Ceiling/Roof

Framing Material: Metal

Framing Spacing: 16 "o.c.

Framing Size:	Actual Depth	14.000
	Actual Width	1.625
Cavity Insulation:	R-value	38.800
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components

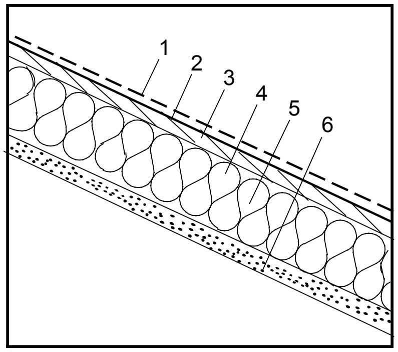
		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle roofing	0.440
2.	Building paper (felt)	0.060
3.	1.50 in Polyisocyanurate	10.560
4.	0.50 in Plywood	0.630
5.	1.50 in Polyisocyanurate	10.560
6.	0.50 in gypsum or plaster board	0.450
7.		
	Inside Surface Air Film	0.620

Calculation:

From EZFRAME = $\underset{\textbf{Total U-factor}}{\boxed{0.027}}$

$$\underset{1\div \text{Total U-factor}}{\underline{1/0.027}} = \underset{\textbf{Total R-Value}}{\underline{36.95}}$$

Reference Name: **R.38.2x12.16**



Sketch of Construction Assembly

Assembly Type:	______	Floor
(check one)	______	Wall
	✓	Ceiling/Roof
Framing Material:	**Wood**	
Framing Size:	2 × 12	
Framing Spacing:	16	"o.c.
Framing (check one)	Wall: ______	15%
	______	12%
	______	9% (48"o.c.)
	Floor/Ceilin ✓	10%
	______	7% (24"o.c.)
	______	4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA	

List of Construction Components

		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.630	0.630
4.	2x12 in fir framing	-----	11.138
5.	R-38 fiberglass insulation	38.000	-----
6.	0.50 in gypsum or plaster board	0.450	0.450
7.			
	Inside Surface Air Film	0.620	0.620
	Total Unadjusted R-Values:	40.370	13.508
		R_c	R_f

Framing Adjustment Calculation:

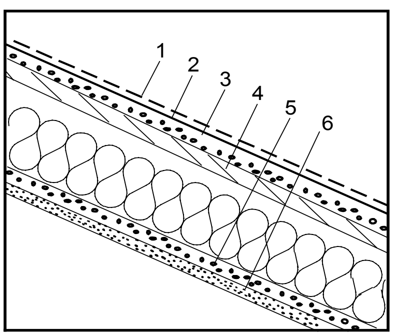
$$[(\underbrace{1/40.370}_{1\div R_c}) \times (\underbrace{1-10/100}_{1-(Fr.\% \div 100)})] + [(\underbrace{1/13.508}_{1\div R_f}) \times (\underbrace{10/100}_{Fr.\% \div 100})] = \boxed{0.030}$$

Total U-factor

$$\underbrace{1/0.030}_{1\div \text{Total U-factor}} = 33.333$$

Total R-Value

Reference Name: **R.38.S2x12.16**



Sketch of Construction Assembly

Assembly Type:	______	Floor
(check one)	______	Wall
	✓	Ceiling/Roof
Framing Material:	**Metal**	
Framing Spacing:	16	"o.c.
Framing Size:	Actual Depth	12.000
	Actual Width	1.625
Cavity Insulation:	R-value	38.800
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components

		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle roofing	0.440
2.	Building paper (felt)	0.060
3.	1.50 in polyisocyanurate	10.560
4.	0.625 in plywood	0.780
5.	1.00 in polyisocyanurate	7.040
6.	0.625 in gypsum or plaster board	0.560
7.		
	Inside Surface Air Film	0.620

Calculation:

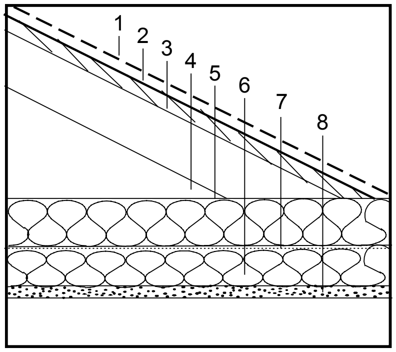
From EZFRAME = $\boxed{0.030}$

Total U-factor

$$\underbrace{1/0.030}_{1\div \text{Total U-factor}} = 33.38$$

Total R-Value

Reference Name: **R.38.2x4.24**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor	
		Wall	
	✓	Ceiling/Roof	
Framing Material:	Wood		
Framing Size:	2 × 4		
Framing Spacing:	24 "o.c.		
Framing (check one)	Wall:		15%
			12%
			9% (48"o.c.)
	Floor/Ceilin		10%
		✓	7% (24"o.c.)
			4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA		

List of Construction Components

		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.630	0.630
4.	3.50 in & greater air space: heat flow up	0.800	0.800
5.	R-27 fiberglass insulation	27.000	27.000
6.	R-11 fiberglass insulation	11.000	-----
7.	2x4 in fir framing	-----	3.465
8.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	41.160 R_c	33.625 R_f

Framing Adjustment Calculation:

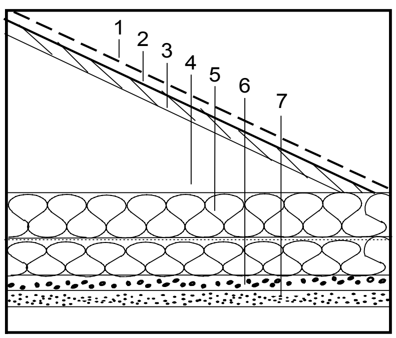
$$\left[\left(\underset{1\div R_c}{1/41.160}\right) \times \left(\underset{1-(\text{Fr.}\% \div 100)}{1-7/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/33.625}\right) \times \left(\underset{\text{Fr.}\% \div 100}{7/100}\right)\right] = \boxed{0.025}$$

Total U-factor

$$\frac{1/0.025}{1\div\text{Total U-factor}} = 40.000$$

Total R-Value

Reference Name: **R.38.S2x4.24**



Sketch of Construction Assembly

Assembly Type: (check one)			Floor
			Wall
		✓	Ceiling/Roof
Framing Material:	Metal		
Framing Spacing:	24 "o.c.		
Framing Size:	Actual Depth	3.625	
	Actual Width	1.625	
Cavity Insulation:	R-value	11.000	
	Knock-out (%)	15.000	
	Web	0.060	
Insulation Tape R-	Interior Flange		
	Exterior		

List of Construction Components

		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle roofing	0.440
2.	Building paper (felt)	0.060
3.	0.50 in Plywood	0.630
4.	3.50 in & greater air space: heat flow up	0.800
5.	R-27 fiberglass insulation	27.000
6.	1.00 in polyisocyanurate	7.040
7.	0.50 in gypsum or plaster board	0.450
	Inside Surface Air Film	0.610

Calculation:

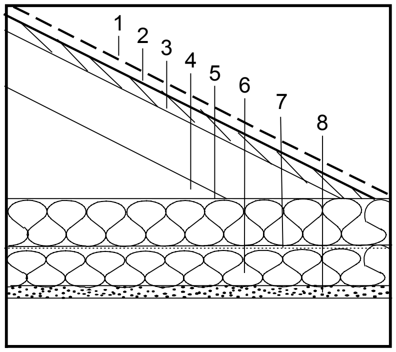
From EZFRAME = $\boxed{0.023}$

Total U-factor

$$\frac{1/0.023}{1\div\text{Total U-factor}} = 43.25$$

Total R-Value

Reference Name: **R.49.2x4.16**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
		Wall
	✓	Ceiling/Roof
Framing Material:	**Wood**	
Framing Size:	2 × 4	
Framing Spacing:	16 "o.c.	
Framing (check one)	Wall:	15%
		12%
		9% (48"o.c.)
	Floor/Ceilin ✓	10%
		7% (24"o.c.)
		4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA	

List of Construction Components / **R-Value**

	Component	Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.630	0.630
4.	3.50 in & greater air space: heat flow up	0.800	0.800
5.	R-38 fiberglass insulation	38.000	38.000
6.	R-11 fiberglass insulation	11.000	-----
7.	2x4 in fir framing	-----	3.465
8.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	52.160	44.625
		R_c	R_f

Framing Adjustment Calculation:

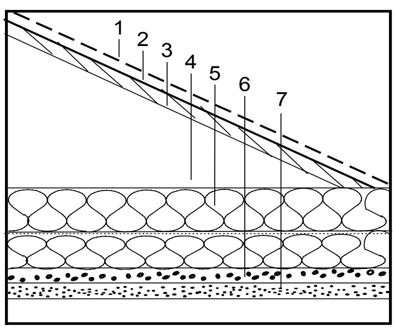
$$\left[\left(\underset{1\div R_c}{1/52.160}\right) \times \left(\underset{1-(\text{Fr.}\%\div 100)}{1-10/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/44.625}\right) \times \left(\underset{\text{Fr.}\%\div 100}{10/100}\right)\right] = \boxed{0.019}$$

Total U-factor

$$\frac{1/0.019}{1\div\text{Total U-factor}} = 52.632$$

Total R-Value

Reference Name: **R.49.S2x4.16**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
		Wall
	✓	Ceiling/Roof
Framing Material:	**Metal**	
Framing Spacing:	16 "o.c.	
Framing Size:	Actual Depth	3.625
	Actual Width	1.625
Cavity Insulation:	R-value	11.000
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components / **R-Value**

	Component	R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle roofing	0.440
2.	Building paper (felt)	0.060
3.	0.50 in plywood	0.630
4.	3.50 in air space	0.800
5.	R-38 fiberglass insulation	38.000
6.	1.00 in polyisocyanurate	7.040
7.	0.50 in gypsum or plaster board	0.450
	Inside Surface Air Film	0.610

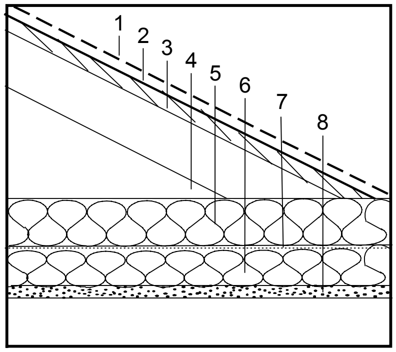
Calculation:

From EZFRAME = $\boxed{0.019}$ **Total U-factor**

$$\frac{1/0.019}{1\div\text{Total U-factor}} = 53.02$$

Total R-Value

Reference Name: **R.49.2x4.24**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
		Wall
	✓	Ceiling/Roof
Framing Material:	**Wood**	
Framing Size:	2 × 4	
Framing Spacing:	24 "o.c.	
Framing (check one)	Wall:	15%
		12%
		9% (48"o.c.)
	Floor/Ceilin	10%
	✓	7% (24"o.c.)
		4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA	

List of Construction Components

	List of Construction Components	R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.630	0.630
4.	3.50 in & greater air space; heat flow up	0.800	0.800
5.	R-38 fiberglass insulation	38.000	38.000
6.	R-11 fiberglass insulation	11.000	-----
7.	2x4 in fir framing	-----	3.465
8.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	52.160	44.625
		R_c	R_f

Framing Adjustment Calculation:

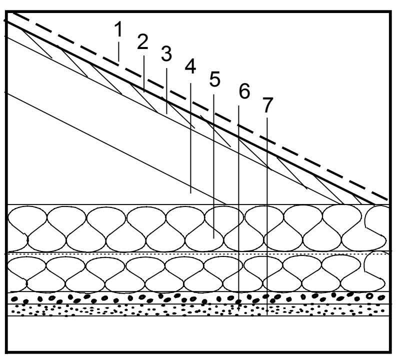
$$\left[\left(\underset{1\div R_c}{1/52.160}\right) \times \left(\underset{1-(\text{Fr.}\%\div 100)}{1-7/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/44.625}\right) \times \left(\underset{\text{Fr.}\%\div 100}{7/100}\right)\right] = \boxed{0.019}$$

Total U-factor

$$\underset{1\div\text{Total U-factor}}{1/0.019} = 52.632$$

Total R-Value

Reference Name: **R.49.S2x4.24**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
		Wall
	✓	Ceiling/Roof
Framing Material:	**Metal**	
Framing Spacing:	24 "o.c.	
Framing Size:	Actual Depth	3.625
	Actual Width	1.625
Cavity Insulation:	R-value	11.000
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components

	List of Construction Components	R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle roofing	0.440
2.	Building paper (felt)	0.060
3.	0.50 in Plywood	0.630
4.	3.50 in & greater air space; heat flow up	0.800
5.	R-38 fiberglass insulation	38.000
6.	0.25 in Polyisocyanurate	1.760
7.	0.75 in gypsum or plaster board	0.680
	Inside Surface Air Film	0.610

Calculation:

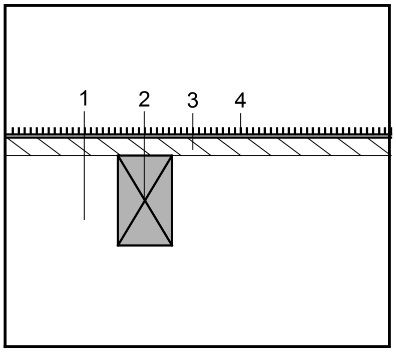
From EZFRAME = $\boxed{0.018}$

Total U-factor

$$\underset{1\div\text{Total U-factor}}{1/0.018} = 54.250$$

Total R-Value

Reference Name: **FC.0.2x6.16**



Sketch of Construction Assembly

Assembly Type:	✓	Floor	
(check one)		Wall	
		Ceiling/Roof	
Framing Material:	**Wood**		
Framing Size:	2 × 6		
Framing Spacing:	16 "o.c.		
Framing (check one)	Wall:		15%
			12%
			9% (48"o.c.)
	Floor/Ceilin	✓	10%
			7% (24"o.c.)
			4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA		

List of Construction Components

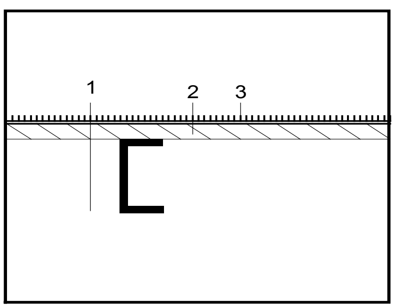
	List of Construction Components	R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Effective R-value of vented crawlspace	6.000	6.000
2.	2x6 in fir framing	-----	5.445
3.	0.625 in plywood	0.780	0.780
4.	Carpet & Pad	2.080	2.080
5.			
6.			
7.			
	Inside Surface Air Film	0.920	0.920
	Total Unadjusted R-Values:	9.950	15.395
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\frac{1/9.950}{1 \div R_c}\right) \times \left(\frac{1-10/100}{1-(\text{Fr.}\% \div 100)}\right)\right] + \left[\left(\frac{1/15.395}{1 \div R_f}\right) \times \left(\frac{10/100}{\text{Fr.}\% \div 100}\right)\right] = \boxed{0.097} \text{ Total U-factor}$$

$$\frac{1/0.097}{1 \div \text{Total U-factor}} = 10.309 \text{ Total R-Value}$$

Reference Name: **FC.0.S2x6.16**



Sketch of Construction Assembly

Assembly Type:	✓	Floor	
(check one)		Wall	
		Ceiling/Roof	
Framing Material:	**Metal**		
Framing Spacing:	16 "o.c.		
Framing Size:	Actual Depth	6.000	
	Actual Width	1.625	
Cavity Insulation:	R-value	0.800	
	Knock-out (%)	15.000	
Insulation Tape R-	Web	0.060	
	Interior Flange		
	Exterior		

List of Construction Components

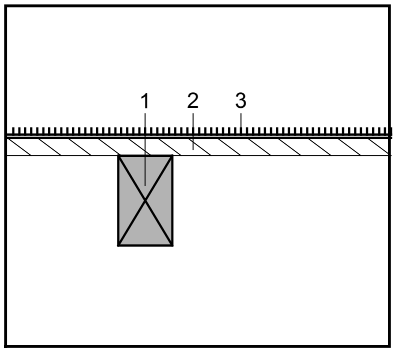
	List of Construction Components	R-Value
	Outside Surface Air Film	0.170
1.	Effective R-value of vented crawlspace	6.000
2.	0.625 in plywood	0.780
3.	Carpet & Pad	2.080
4.		
5.		
6.		
7.		
	Inside Surface Air Film	0.920

Calculation:

From EZFRAME = $\boxed{0.094}$ Total U-factor

$$\frac{1/0.094}{1 \div \text{Total U-factor}} = 10.680 \text{ Total R-Value}$$

Reference Name: **FX.0.2x6.16**



Sketch of Construction Assembly

Assembly Type: (check one) ✓ Floor; Wall; Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 6

Framing Spacing: 16 "o.c.

Framing (check one)

Wall:		15%
		12%
		9% (48"o.c.)
Floor/Ceilin	✓	10%
		7% (24"o.c.)
		4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components

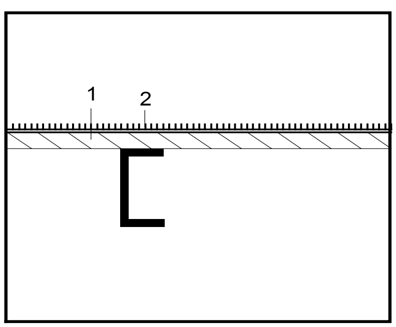
		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	2x6 in fir framing	-----	5.445
2.	0.625 in plywood	0.780	0.780
3.	Carpet & Pad	2.080	2.080
4.			
5.			
6.			
7.			
	Inside Surface Air Film	0.920	0.920
	Total Unadjusted R-Values:	3.950	9.395
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\underset{1 \div R_c}{\underline{1/3.950}}\right) \times \left(\underset{1-(\text{Fr.\%} \div 100)}{\underline{1-10/100}}\right)\right] + \left[\left(\underset{1 \div R_f}{\underline{1/9.395}}\right) \times \left(\underset{\text{Fr.\%} \div 100}{\underline{10/100}}\right)\right] = \boxed{0.238} \text{ Total U-factor}$$

$$\underset{1 \div \text{Total U-factor}}{\underline{1/0.238}} = \underset{\textbf{Total R-Value}}{\underline{4.202}}$$

Reference Name: **FX.0.S2x6.16**



Sketch of Construction Assembly

Assembly Type: (check one) ✓ Floor; Wall; Ceiling/Roof

Framing Material: Metal

Framing Spacing: 16 "o.c.

Framing Size: Actual Depth 6.000; Actual Width 1.625

Cavity Insulation: R-value 0.800; Knock-out (%) 15.000; Web 0.060

Insulation Tape R- Interior Flange ____; Exterior ____

List of Construction Components

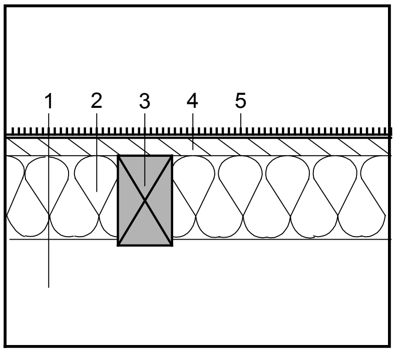
		R-Value
	Outside Surface Air Film	0.170
1.	0.625 in plywood	0.780
2.	Carpet & pad	2.080
3.		
4.		
5.		
6.		
7.		
	Inside Surface Air Film	0.920

Calculation:

From EZFRAME = $\boxed{0.253}$ **Total U-factor**

$$\underset{1 \div \text{Total U-factor}}{\underline{1/0.253}} = \underset{\textbf{Total R-Value}}{\underline{3.950}}$$

Reference Name: **FC.11.2x6.16**



Sketch of Construction Assembly

Assembly Type: (check one)	✓	Floor	
		Wall	
		Ceiling/Roof	
Framing Material:	Wood		
Framing Size:	2 × 6		
Framing Spacing:	16 "o.c.		
Framing (check one)	Wall:		15%
			12%
			9% (48"o.c.)
	Floor/Ceilin	✓	10%
			7% (24"o.c.)
			4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA		

List of Construction Components

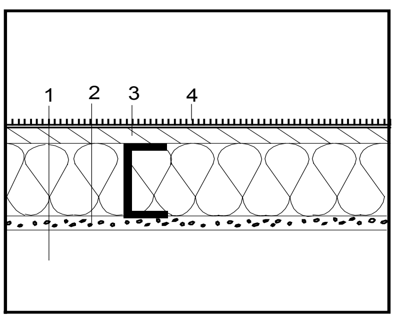
	List of Construction Components	R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Effective R-value of vented crawlspace	6.000	6.000
2.	R-11 fiberglass insulation	11.000	-----
3.	2x6 in fir framing	-----	5.445
4.	0.625 in plywood	0.780	0.780
5.	Carpet & pad	2.080	2.080
6.			
7.			
	Inside Surface Air Film	0.920	0.920
	Total Unadjusted R-Values:	20.950	15.395
		R_c	**R_f**

Framing Adjustment Calculation:

$$\left[\left(\underset{1\div R_c}{1/20.950}\right) \times \left(\underset{1-(\text{Fr.\%} \div 100)}{1-10/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/15.395}\right) \times \left(\underset{\text{Fr.\%} \div 100}{10/100}\right)\right] = \boxed{0.049}\ \textbf{Total U-factor}$$

$$\underset{1\div\text{Total U-factor}}{1/0.049} = 20.408\ \textbf{Total R-Value}$$

Reference Name: **FC.11.S2x6.16**



Sketch of Construction Assembly

Assembly Type: (check one)	✓	Floor	
		Wall	
		Ceiling/Roof	
Framing Material:	Metal		
Framing Spacing:	16 "o.c.		
Framing Size:		Actual Depth	6.000
		Actual Width	1.625
Cavity Insulation:		R-value	11.000
		Knock-out (%)	15.000
		Web	0.060
Insulation Tape R-		Interior Flange	
		Exterior	

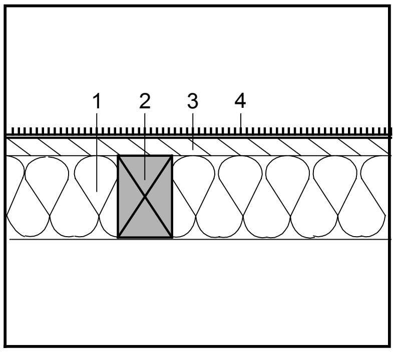
	List of Construction Components	R-Value
	Outside Surface Air Film	0.170
1.	Effective R-value of vented crawlspace	6.000
2.	0.75 in polyisocyanurate	5.280
3.	0.625 in plywood	0.780
4.	Carpet & pad	2.080
5.		
6.		
7.		
	Inside Surface Air Film	0.920

Calculation:

From EZFRAME = $\boxed{0.048}$ **Total U-factor**

$$\underset{1\div\text{Total U-factor}}{1/0.048} = 21.030\ \textbf{Total R-Value}$$

Reference Name: **FX.11.2x6.16**



Sketch of Construction Assembly

Assembly Type: (check one)	✓	Floor	
		Wall	
		Ceiling/Roof	
Framing Material:	Wood		
Framing Size:	2 × 6		
Framing Spacing:	16 "o.c.		
Framing (check one)	Wall:		15%
			12%
			9% (48"o.c.)
	Floor/Ceilin	✓	10%
			7% (24"o.c.)
			4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA		

List of Construction Components

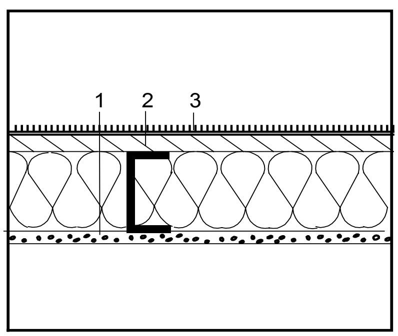
		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	R-11 fiberglass insulation	11.000	-----
2.	2x6 in fir framing	-----	5.445
3.	0.625 in plywood	0.780	0.780
4.	Carpet & pad	2.080	2.080
5.			
6.			
7.			
	Inside Surface Air Film	0.920	0.920
	Total Unadjusted R-Values:	14.940	9.395
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\frac{1/14.950}{1 \div R_c}\right) \times \left(\frac{1\text{-}10/100}{1\text{-}(\text{Fr.\%} \div 100)}\right)\right] + \left[\left(\frac{1/9.395}{1 \div R_f}\right) \times \left(\frac{10/100}{\text{Fr.\%} \div 100}\right)\right] = \boxed{0.071} \text{ Total U-factor}$$

$$\frac{1/0.071}{1 \div \text{Total U-factor}} = 14.085 \text{ Total R-Value}$$

Reference Name: **FX.11.S2x6.16**



Sketch of Construction Assembly

Assembly Type: (check one)	✓	Floor	
		Wall	
		Ceiling/Roof	
Framing Material:	Metal		
Framing Spacing:	16 "o.c.		
Framing Size:	Actual Depth	6.000	
	Actual Width	1.625	
Cavity Insulation:	R-value	11.000	
	Knock-out (%)	15.000	
	Web	0.060	
Insulation Tape R-	Interior Flange		
	Exterior		

List of Construction Components

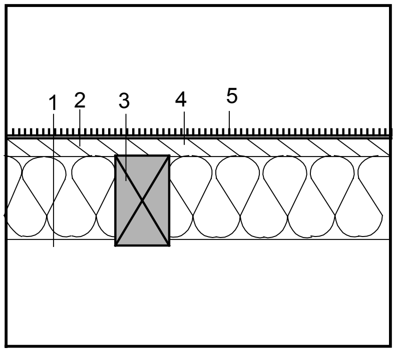
		R-Value
	Outside Surface Air Film	0.170
1.	0.75 in polyisocyanurate	5.280
2.	0.625 in plywood	0.780
3.	Carpert & pad	2.080
4.		
5.		
6.		
7.		
	Inside Surface Air Film	0.920

Calculation:

From EZFRAME = $\boxed{0.071}$ **Total U-factor**

$$\frac{1/0.071}{1 \div \text{Total U-factor}} = 14.16 \text{ Total R-Value}$$

Reference Name: **FC.13.2x6.16**



Sketch of Construction Assembly

Assembly Type: (check one)	✓	Floor	
		Wall	
		Ceiling/Roof	
Framing Material:	**Wood**		
Framing Size:	2 × 6		
Framing Spacing:	16 “o.c.		
Framing (check one)	Wall:		15%
			12%
			9% (48”o.c.)
	Floor/Ceilin	✓	10%
			7% (24”o.c.)
			4% (48”o.c.)
Wall Weight / sf: (Packages only)	NA		

List of Construction Components

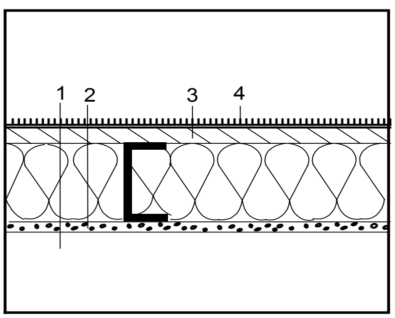
		R-Value Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Effective R-Value of vented crawlspace	6.000	6.000
2.	R-13 fiberglass insulation	13.000	-----
3.	2x6 in fir framing	-----	5.445
4.	0.625 in plywood	0.780	0.780
5.	Carpet & pad	2.080	2.080
6.			
7.			
	Inside Surface Air Film	0.920	0.920
	Total Unadjusted R-Values:	22.950	15.395
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\underset{1\div R_c}{1/22.950}\right) \times \left(\underset{1-(\text{Fr.\%} \div 100)}{1-10/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/15.395}\right) \times \left(\underset{\text{Fr.\%} \div 100}{10/100}\right)\right] = \underset{\textbf{Total U-factor}}{\boxed{0.046}}$$

$$\underset{1\div\text{Total U-factor}}{1/0.046} = \underset{\textbf{Total R-Value}}{21.740}$$

Reference Name: **FC.13.S2x6.16**



Sketch of Construction Assembly

Assembly Type: (check one)	✓	Floor	
		Wall	
		Ceiling/Roof	
Framing Material:	**Metal**		
Framing Spacing:	16 “o.c.		
Framing Size:		Actual Depth	6.000
		Actual Width	1.625
Cavity Insulation:		R-value	13.000
		Knock-out (%)	15.000
		Web	0.060
Insulation Tape R-		Interior Flange	
		Exterior	

List of Construction Components

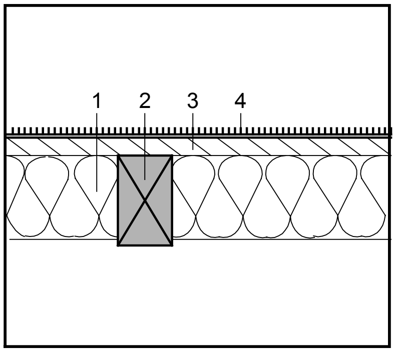
		R-Value
	Outside Surface Air Film	0.170
1.	Effective R-Value of vented crawlspace	6.000
2.	1.00 in polyisocyanurate	7.040
3.	0.625 in plywood	0.780
4.	Carpet & pad	2.080
5.		
6.		
7.		
	Inside Surface Air Film	0.920

Calculation:

From EZFRAME = $\underset{\textbf{Total U-factor}}{\boxed{0.043}}$

$$\underset{1\div\text{Total U-factor}}{1/0.043} = \underset{\textbf{Total R-Value}}{23.340}$$

Reference Name: **FX.13.2x6.16**



Sketch of Construction Assembly

Assembly Type: (check one)	✓	Floor	
		Wall	
		Ceiling/Roof	
Framing Material:	**Wood**		
Framing Size:	2	×	6
Framing Spacing:	16	"o.c.	
Framing (check one)	Wall:		15%
			12%
			9% (48"o.c.)
	Floor/Ceilin	✓	10%
			7% (24"o.c.)
			4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA		

List of Construction Components / **R-Value**

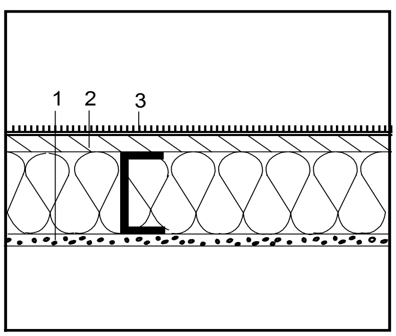
		Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	R-13 fiberglass insulation	13.000	-----
2.	2x6 in fir framing	-----	5.445
3.	0.625 in plywood	0.780	0.780
4.	Carpet & pad	2.080	2.080
5.			
6.			
7.			
	Inside Surface Air Film	0.920	0.920
	Total Unadjusted R-Values:	16.950	9.395
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\underset{1\div R_c}{1/16.950}\right) \times \left(\underset{1\text{-(Fr.\% }\div 100)}{1\text{-}10/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/9.395}\right) \times \left(\underset{\text{Fr.\% }\div 100}{10/100}\right)\right] = \boxed{0.064}\ \text{Total U-factor}$$

$$\underset{1\div\text{Total U-factor}}{1/0.064} = \underset{\textbf{Total R-Value}}{15.625}$$

Reference Name: **FX.13.S2x6.16**



Sketch of Construction Assembly

Assembly Type: (check one)	✓	Floor
		Wall
		Ceiling/Roof
Framing Material:	**Metal**	
Framing Spacing:	16	"o.c.
Framing Size:	Actual Depth	6.000
	Actual Width	1.625
Cavity Insulation:	R-value	13.000
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components / **R-Value**

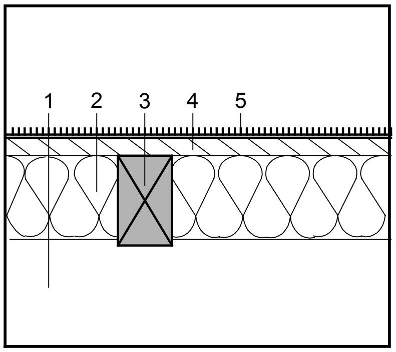
		R-Value
	Outside Surface Air Film	0.170
1.	1.00 in polyisocyanurate	7.040
2.	0.625 in plywood	0.780
3.	Carpet & pad	2.080
4.		
5.		
6.		
7.		
	Inside Surface Air Film	0.920

Calculation:

From EZFRAME = $\boxed{0.058}$ **Total U-factor**

$$\underset{1\div\text{Total U-factor}}{1/0.058} = \underset{\textbf{Total R-Value}}{17.340}$$

Reference Name: **FC.19.2x8.16**



Sketch of Construction Assembly

Assembly Type: (check one) ✓ Floor; ___ Wall; ___ Ceiling/Roof

Framing Material: **Wood**

Framing Size: 2 × 8

Framing Spacing: 16 "o.c.

Framing (check one)

Wall:		15%
		12%
		9% (48"o.c.)
Floor/Ceilin	✓	10%
		7% (24"o.c.)
		4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components

		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Effective R-value of vented crawlspace	6.000	6.000
2.	R-19 fiberglass insulation	19.000	-----
3.	7.25 in fir framing	-----	7.178
4.	0.625 in plywood	0.780	0.780
5.	Carpet & pad	2.080	2.080
6.			
7.			
	Inside Surface Air Film	0.920	0.920
	Total Unadjusted R-Values:	28.950	17.128
		R_c	R_f

Framing Adjustment Calculation:

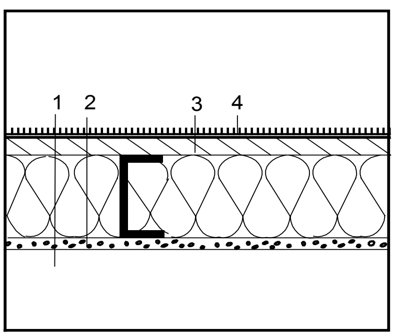
$$\left[\left(\underset{1\div R_c}{\underline{1/28.950}}\right) \times \left(\underset{1-(\text{Fr.\%}\div 100)}{\underline{1-10/100}}\right)\right] + \left[\left(\underset{1\div R_f}{\underline{1/17.128}}\right) \times \left(\underset{\text{Fr.\%}\div 100}{\underline{10/100}}\right)\right] = \boxed{0.037}$$

Total U-factor

$$\underset{1\div\text{Total U-factor}}{\underline{1/0.037}} = \underline{27.027}$$

Total R-Value

Reference Name: **FC.19.S2x8.16**



Sketch of Construction Assembly

Assembly Type: (check one) ✓ Floor; ___ Wall; ___ Ceiling/Roof

Framing Material: **Metal**

Framing Spacing: 16 "o.c.

Framing Size:	Actual Depth	8.00
	Actual Width	1.625
Cavity Insulation:	R-value	19.000
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components

		R-Value
	Outside Surface Air Film	0.170
1.	Effective R-value of vented crawlspace	6.000
2.	1.50 in polyisocyanurate	10.560
3.	0.625 in plywood	0.780
4.	Carpet & pad	2.080
5.		
6.		
7.		
	Inside Surface Air Film	0.920

Calculation:

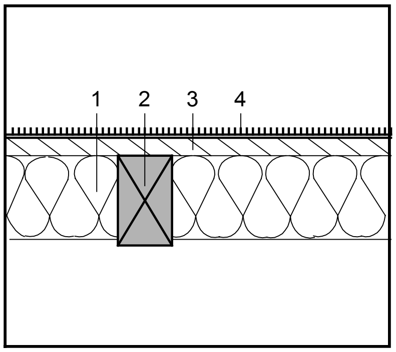
From EZFRAME = $\boxed{0.035}$

Total U-factor

$$\underset{1\div\text{Total U-factor}}{\underline{1/0.035}} = \underline{28.700}$$

Total R-Value

Reference Name: **FX.19.2x8.16**



Sketch of Construction Assembly

Assembly Type: (check one)	✓	Floor	
		Wall	
		Ceiling/Roof	
Framing Material:	**Wood**		
Framing Size:	2 × 8		
Framing Spacing:	16 “o.c.		
Framing (check one)	Wall:		15%
			12%
			9% (48”o.c.)
	Floor/Ceilin	✓	10%
			7% (24”o.c.)
			4% (48”o.c.)
Wall Weight / sf: (Packages only)	NA		

List of Construction Components / **R-Value**

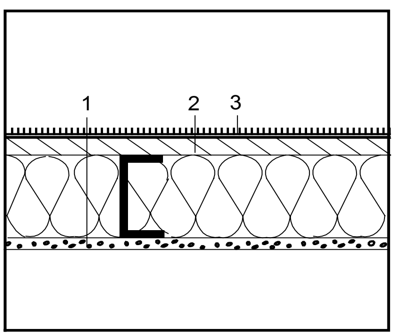
	Component	Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	R-19 fiberglass insulation	19.000	-----
2.	7.25 in fir framing	-----	7.178
3.	0.625 in plywood	0.780	0.780
4.	Carpet & pad	2.080	2.080
5.			
6.			
7.			
	Inside Surface Air Film	0.920	0.920
	Total Unadjusted R-Values:	22.950	11.128
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\frac{1/22.950}{1 \div R_c}\right) \times \left(\frac{1-10/100}{1-(\text{Fr.}\% \div 100)}\right)\right] + \left[\left(\frac{1/11.128}{1 \div R_f}\right) \times \left(\frac{10/100}{\text{Fr.}\% \div 100}\right)\right] = \boxed{0.049}\ \textbf{Total U-factor}$$

$$\frac{1/0.049}{1 \div \text{Total U-factor}} = 20.408\ \textbf{Total R-Value}$$

Reference Name: **FX.19.S2x8.16**



Sketch of Construction Assembly

Assembly Type: (check one)	✓	Floor
		Wall
		Ceiling/Roof
Framing Material:	**Metal**	
Framing Spacing:	16 “o.c.	
Framing Size:	Actual Depth	8.000
	Actual Width	1.625
Cavity Insulation:	R-value	19.000
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components / **R-Value**

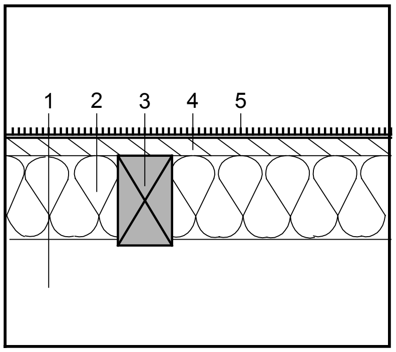
	Component	R-Value
	Outside Surface Air Film	0.170
1.	1.25 in polyisocyanurate	8.800
2.	0.625 in plywood	0.780
3.	Carpet & pad	2.080
4.		
5.		
6.		
7.		
	Inside Surface Air Film	0.920

Calculation:

From EZFRAME = $\boxed{0.048}$ **Total U-factor**

$$\frac{1/0.048}{1 \div \text{Total U-factor}} = 20.950\ \textbf{Total R-Value}$$

Reference Name: **FC.21.2x8.16**



Sketch of Construction Assembly

Assembly Type: (check one): ✓ Floor; ___ Wall; ___ Ceiling/Roof

Framing Material: **Wood**

Framing Size: 2 × 8

Framing Spacing: 16 "o.c.

Framing (check one):

Wall:		15%
		12%
		9% (48"o.c.)
Floor/Ceilin	✓	10%
		7% (24"o.c.)
		4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components

	List of Construction Components	R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Effective R-value of vented crawlspace	6.000	6.000
2.	R-21 fiberglass insulation	21.000	-----
3.	7.25 in fir framing	-----	7.178
4.	0.625 in plywood	0.780	0.780
5.	Carpet & pad	2.080	2.080
6.			
7.			
	Inside Surface Air Film	0.920	0.920
	Total Unadjusted R-Values:	30.950	17.128
		R_c	R_f

Framing Adjustment Calculation:

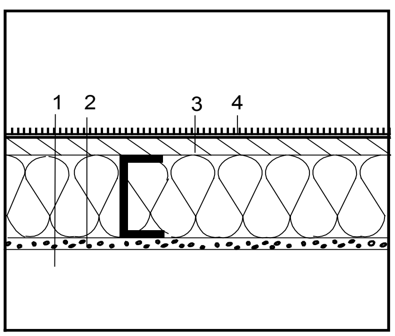
$$\left[\left(\underset{1\div R_c}{1/30.950}\right) \times \left(\underset{1-(\text{Fr.\%} \div 100)}{1-10/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/17.128}\right) \times \left(\underset{\text{Fr.\%} \div 100}{10/100}\right)\right] = \boxed{0.032}$$

Total U-factor

$$\underset{1\div\text{Total U-factor}}{1/0.032} = 31.250$$

Total R-Value

Reference Name: **FC.21.S2x8.16**



Sketch of Construction Assembly

Assembly Type: (check one): ✓ Floor; ___ Wall; ___ Ceiling/Roof

Framing Material: **Metal**

Framing Spacing: 16 "o.c.

Framing Size:	Actual Depth	8.000
	Actual Width	1.625
Cavity Insulation:	R-value	21.000
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components

	List of Construction Components	R-Value
	Outside Surface Air Film	0.170
1.	Effective R-value of vented crawlspace	6.000
2.	1.50 in polyisocyanurate	10.560
3.	0.625 in plywood	0.780
4.	Carpet & pad	2.080
5.		
6.		
7.		
	Inside Surface Air Film	0.920

Calculation:

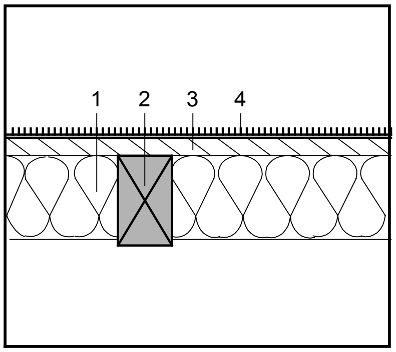
From EZFRAME = $\boxed{0.034}$

Total U-factor

$$\underset{1\div\text{Total U-factor}}{1/0.034} = 29.080$$

Total R-Value

Reference Name: **FX.21.2x8.16**



Sketch of Construction Assembly

Assembly Type: (check one)

✓	Floor	
	Wall	
	Ceiling/Roof	

Framing Material: Wood

Framing Size: 2 × 8

Framing Spacing: 16 "o.c.

Framing (check one)

Wall:		15%
		12%
		9% (48"o.c.)
Floor/Ceilin	✓	10%
		7% (24"o.c.)
		4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components

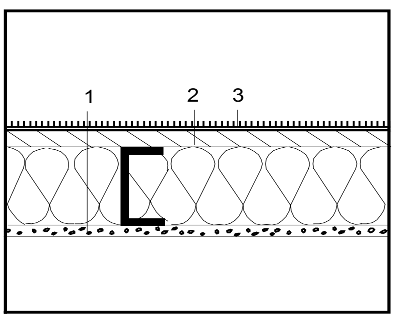
		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	R-21 fiberglass insulation	21.000	-----
2.	7.25 in fir framing	-----	7.178
3.	0.625 in plywood	0.780	0.780
4.	Carpet & pad	2.080	2.080
5.			
6.			
7.			
	Inside Surface Air Film	0.920	0.920
	Total Unadjusted R-Values:	24.950	11.128
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\underset{1\div R_c}{1/24.950}\right) \times \left(\underset{1-(\text{Fr.\%}\div 100)}{1-10/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/11.128}\right) \times \left(\underset{\text{Fr.\%}\div 100}{10/100}\right)\right] = \underset{\textbf{Total U-factor}}{\boxed{0.045}}$$

$$\underset{1\div\text{Total U-factor}}{1/0.045} = \underset{\textbf{Total R-Value}}{22.222}$$

Reference Name: **FX.21.S2x8.16**



Sketch of Construction Assembly

Assembly Type: (check one)

✓	Floor	
	Wall	
	Ceiling/Roof	

Framing Material: Metal

Framing Spacing: 16 "o.c.

Framing Size:	Actual Depth	8.000
	Actual Width	1.625
Cavity Insulation:	R-value	21.000
	Knock-out (%)	15.000
	Web	0.060
Insulation Tape R-	Interior Flange	
	Exterior	

List of Construction Components

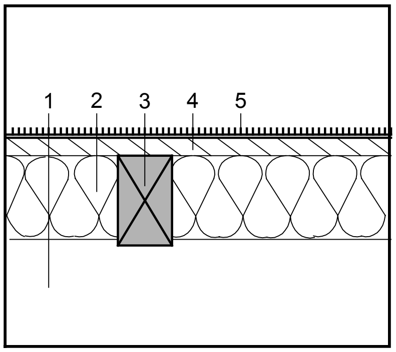
		R-Value
	Outside Surface Air Film	0.170
1.	1.50 in polyisocyanurate	10.560
2.	0.625 in plywood	0.780
3.	Carpet & pad	2.080
4.		
5.		
6.		
7.		
	Inside Surface Air Film	0.920

Calculation:

$$\text{From EZFRAME} = \underset{\textbf{Total U-factor}}{\boxed{0.043}}$$

$$\underset{1\div\text{Total U-factor}}{1/0.043} = \underset{\textbf{Total R-Value}}{23.080}$$

Reference Name: **FC.30.2x10.16**



Sketch of Construction Assembly

Assembly Type: (check one)	✓	Floor	
		Wall	
		Ceiling/Roof	
Framing Material:	**Wood**		
Framing Size:	2 × 8		
Framing Spacing:	16 “o.c.		
Framing (check one)	Wall:		15%
			12%
			9% (48”o.c.)
	Floor/Ceilin	✓	10%
			7% (24”o.c.)
			4% (48”o.c.)
Wall Weight / sf: (Packages only)	NA		

List of Construction Components

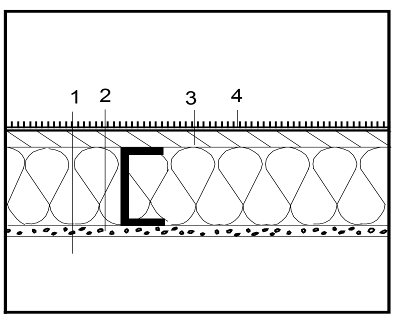
		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Effective R-value of vented crawlspace	6.000	6.000
2.	R-30 fiberglass insulation	30.000	-----
3.	9.25 in fir framing	-----	9.158
4.	0.625 in plywood	0.780	0.780
5.	Carpet & pad	2.080	2.080
6.			
7.			
	Inside Surface Air Film	0.920	0.920
	Total Unadjusted R-Values:	39.950	19.028
		R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\frac{1/39.950}{1\div R_c}\right) \times \left(\frac{1-10/100}{1-(\text{Fr.\%}\div 100)}\right)\right] + \left[\left(\frac{1/19.028}{1\div R_f}\right) \times \left(\frac{10/100}{\text{Fr.\%}\div 100}\right)\right] = \underset{\textbf{Total U-factor}}{\boxed{0.028}}$$

$$\frac{1/0.028}{1\div\text{Total U-factor}} = \underset{\textbf{Total R-Value}}{35.714}$$

Reference Name: **FC.30.S2x10.16**



Sketch of Construction Assembly

Assembly Type: (check one)	✓	Floor	
		Wall	
		Ceiling/Roof	
Framing Material:	**Metal**		
Framing Spacing:	16 “o.c.		
Framing Size:		Actual Depth	10.000
		Actual Width	1.625
Cavity Insulation:		R-value	30.000
		Knock-out (%)	15.000
		Web	0.060
Insulation Tape R-		Interior Flange	
		Exterior	

List of Construction Components

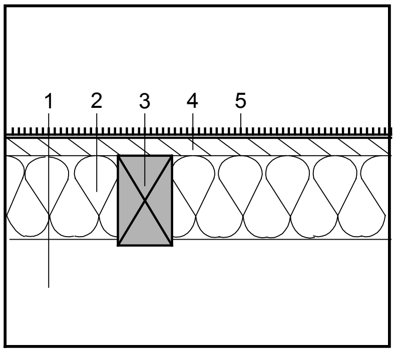
		R-Value
	Outside Surface Air Film	0.170
1.	Effective R-value of vented crawlspace	6.000
2.	2.50 in polyisocyanurate	17.600
3.	0.625 in plywood	0.780
4.	Carpet & pad	2.080
5.		
6.		
7.		
	Inside Surface Air Film	0.920

Calculation:

From EZFRAME $= \underset{\textbf{Total U-factor}}{\boxed{0.026}}$

$$\frac{1/0.026}{1\div\text{Total U-factor}} = \underset{\textbf{Total R-Value}}{38.110}$$

Reference Name: **FX.30.2x10.16**



Sketch of Construction Assembly

Assembly Type: (check one)	✓	Floor	
		Wall	
		Ceiling/Roof	
Framing Material:	**Wood**		
Framing Size:	2 × 8		
Framing Spacing:	16 "o.c.		
Framing (check one)	Wall:		15%
			12%
			9% (48"o.c.)
	Floor/Ceilin	✓	10%
			7% (24"o.c.)
			4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA		

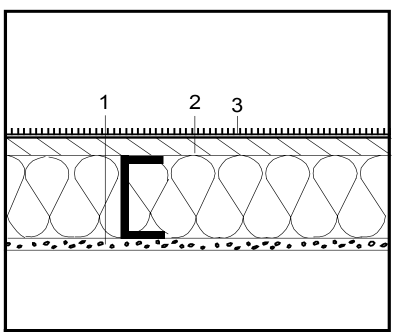
List of Construction Components	**R-Value** Cavity (R_c)	Frame (R_f)
Outside Surface Air Film	0.170	0.170
1. R-30 fiberglass insulation	30.000	-----
2. 9.25 in fir framing	-----	9.158
3. 0.625 in plywood	0.780	0.780
4. Carpet & pad	2.080	2.080
5.		
6.		
7.		
Inside Surface Air Film	0.920	0.920
Total Unadjusted R-Values:	33.950	13.108
	R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\underset{1\div R_c}{1/33.950}\right) \times \left(\underset{1-(\text{Fr.\%}\div 100)}{1-10/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/13.108}\right) \times \left(\underset{\text{Fr.\%}\div 100}{10/100}\right)\right] = \underset{\textbf{Total U-factor}}{\boxed{\mathbf{0.034}}}$$

$$\underset{1\div\text{Total U-factor}}{1/0.034} = \underset{\textbf{Total R-Value}}{29.412}$$

Reference Name: **FX.30.S2x10.16**



Sketch of Construction Assembly

Assembly Type: (check one)	✓	Floor	
		Wall	
		Ceiling/Roof	
Framing Material:	**Metal**		
Framing Spacing:	16 "o.c.		
Framing Size:		Actual Depth	10.000
		Actual Width	1.625
Cavity Insulation:		R-value	38.000
		Knock-out (%)	15.000
		Web	0.060
Insulation Tape R-		Interior Flange	
		Exterior	

List of Construction Components	**R-Value**
Outside Surface Air Film	0.170
1. 2.50 in polyisocyanurate	17.600
2. 0.625 in plywood	0.780
3. Carpet & pad	2.080
4.	
5.	
6.	
7.	
Inside Surface Air Film	0.920

Calculation:

From EZFRAME = $\underset{\textbf{Total U-factor}}{\boxed{\mathbf{0.031}}}$

$$\underset{1\div\text{Total U-factor}}{1/0.031} = \underset{\textbf{Total R-Value}}{32.110}$$

Computer Modeling of Framed Assemblies

EZFrame can be purchased by ordering the following:

Publication No.:	P400-94-002R
Cost:	$14.00
Address:	California Energy Commission Publications, MS-13 P.O. Box 944295 Sacramento, CA 94244-2950

For Questions call the Energy Hotline at 1-800-772-3300 (California Only) or 916-654-5106

Table B-8A–Fan Motor Efficiencies (< 1 HP)

Nameplate or Brake Horsepower	Standard Fan Motor Efficiency	NEMA* High Efficiency	Premium Efficiency
1/20	40%	...	...
1/12	49%	...	...
1/8	55%	...	...
1/6	60%	...	...
1/4	64%	...	...
1/3	66%	...	...
1/2	70%	76.0%	80.0%
3/4	72%	77.0%	84.0%

NOTE: For default drive efficiencies, See Section 4.2.2

*NEMA - Proposed standard using test procedures.
Minimum NEMA efficiency per test IEEE 112b Rating Method.

Table B-8B–Fan Motor Efficiencies (1 HP and over)

	Open Motors				Enclosed Motors			
Number of Poles Synchronous Speed	**2** **3600**	**4** **1800**	**6** **1200**	**8** **900**	**2** **3600**	**4** **1800**	**6** **1200**	**8** **900**
1	—	82.5	80.0	74.0	75.5	82.5	80.0	74.0
1.5	82.5	84.0	84.0	75.5	82.5	84.0	85.5	77.0
2	84.0	84.0	85.5	85.5	84.0	84.0	86.5	82.5
3	84.0	86.5	86.5	86.5	85.5	87.5	87.5	84.0
5	85.5	87.5	87.5	87.5	87.5	87.5	87.5	85.5
7.5	87.5	88.5	88.5	88.5	88.5	89.5	89.5	85.5
10	88.5	89.5	90.2	89.5	89.5	89.5	89.5	88.5
15	89.5	91.0	92.0	89.5	90.2	91.0	90.2	88.5
20	90.2	91.0	91.0	90.2	90.2	91.0	90.2	89.5
25	91.0	91.7	91.7	90.2	91.0	92.4	91.7	89.5
30	91.0	92.4	92.4	91.0	91.0	92.4	91.7	91.0
40	91.7	93.0	93.0	91.0	91.7	93.0	93.0	91.0
50	92.4	93.0	93.0	91.7	92.4	93.0	93.0	91.7
60	93.0	93.6	93.6	92.4	93.0	93.6	93.6	91.7
75	93.0	94.1	93.6	93.6	93.0	94.1	93.6	93.0
100	93.0	94.1	94.1	93.6	93.6	94.5	94.1	93.0
125	93.6	94.5	94.1	93.6	94.5	94.5	94.1	93.6
150	93.6	95.0	94.5	93.6	94.5	95.0	95.0	93.6
200	94.5	95.0	94.5	93.6	95.0	95.0	95.0	94.1
250	94.5	95.0	95.4	94.5	95.4	95.0	95.0	94.5
300	95.0	95.4	95.4	—	95.4	95.4	95.0	—
350	95.0	95.4	95.4	—	95.4	95.4	95.0	—
400	95.4	95.4	—	—	95.4	95.4	—	—
450	95.8	95.8	—	—	95.4	95.4	—	—
500	95.8	95.8	—	—	95.4	95.8	—	—

Table B-9A– ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS – MINIMUM EFFICIENCY REQUIREMENTS (TABLE 1-C1)

Equipment Type	Size Category	Sub-Category or Rating Condition	Efficiency prior to 10/29/2001[a]	Efficiency as of 10/29/2001[a]	Test Procedure
Air Conditioners, Air Cooled	≥65,000 Btu/h and < 135,000 Btu/h	Split System and Single Package	8.9 EER and 8.3 IPLV	10.3 EER[b]	ARI 210/240
	≥135,000 Btu/h and < 240,000 Btu/h	Split System and Single Package	8.5 EER and 7.5 IPLV	9.7 EER[b]	ARI 340/360
	≥ 240,000 Btu/h and <760,000 Btu/h	Split System and Single Package	8.5 EER and 7.5 IPLV	9.5 EER[b] and 9.7 IPLV[b]	
	≥760,000 Btu/h	Split System and Single Package	8.2 EER and 7.5 IPLV	9.2 EER[b] and 9.4 IPLV[b]	
Air Conditioners, Water and Evaporatively Cooled	> 65,000 Btu/h and < 135,000 Btu/h	Split System and Single Package	10.5 EER and 9.7 IPLV	11.5 EER[b]	ARI 210/240
	≥135,000 Btu/h and ≤240,000 Btu/h	Split System and Single Package	9.6 EER 9.0 IPLV	11.0 EER[b]	ARI 340/360
	> 240,000 Btu/h	Split System and Single Package	9.6 EER 9.0 IPLV	11.0 EER[b] and 10.3 IPLV[b]	
Condensing Units, Air Cooled	≥135,000 Btu/h		9.9 EER 11.0 IPLV	10.1 EER and 11.2 IPLV	ARI 365
Condensing Units, Water or Evaporatively Cooled	≥135,000 Btu/h		12.9 EER 12.9 IPLV	13.1 EER and 13.1 IPLV	

[a] IPLVs are only applicable to equipment with capacity modulation.

[b] Deduct 0.2 from the required EERs and IPLVs for units with a heating section other than electric resistance heat.

Table B-9B– UNITARY AND APPLIED HEAT PUMPS, ELECTRICALLY OPERATED – MINIMUM EFFICIENCY REQUIREMENTS (TABLE 1-C2)

Equipment Type	Size Category	Sub-Category or Rating Condition	Efficiency prior to 10/29/2001	Efficiency as of 10/29/2001[a]	Test Procedure
Air Cooled, (Cooling Mode)	≥65,000 Btu/h and < 135,000 Btu/h	Split System and Single Package	8.9 EER 8.3 IPLV	10.1 EER[b]	ARI 210/240
	≥135,000 Btu/h and <240,000 Btu/h	Split System and Single Package	8.5 EER 7.5 IPLV	9.3 EER[b]	ARI 340/360
	≥240,000 Btu/h <760,000 Btu/h	Split System and Single Package	8.5 EER 7.5 IPLV	9.0 EER[b] 9.2 IPLV[b]	
	≥760,000 Btu/h □	Split System and Single Package	8.2 EER 7.5 IPLV	9.0 EER[b] 9.2 IPLV[b]	
Water-Source (Cooling Mode)	< 17,000 Btu/h	85°F Entering Water	10.0 EER		ARI 320
		86°F Entering Water		11.2 EER	ARI/ISO-13256-1
	≥ 17,000 Btu/h and <65,000 Btu/h	85°F Entering Water	10.0 EER		ARI 320
		86°F Entering Water		12.0 EER	ARI/ISO-13256-1
	≥65,000 Btu/h and < 135,000 Btu/h	85°F Entering Water	10.5 EER		ARI 320
		86°F Entering Water		12.0 EER	ARI/ISO-13256-1
Groundwater-Source (Cooling Mode)	< 135,000 Btu/h	70°F Entering Water	11.0 EER		ARI 325
		59°F Entering Water		16.2 EER	ARI/ISO-13256-1
Ground Source (Cooling Mode)	< 135,000 Btu/h	77°F Entering Water	N/A	13.4 EER	ARI/ISO-13256-1
Air Cooled (Heating Mode)	≥65,000 Btu/h and < 135,000 Btu/h (Cooling Capacity)	47°F db/43°F wb Outdoor Air	3.0 COP	3.2 COP	ARI 210/240
	≥135,000 Btu/h (Cooling Capacity)	47°F db/43°F wb Outdoor Air	2.9 COP	3.1 COP	ARI 340/360
Water-Source (Heating Mode)	< 135,000 Btu/h (Cooling Capacity)	70°F Entering Water	3.8 COP		ARI 320
		68°F Entering Water		4.2 COP	ARI/ISO-13256-1
Groundwater-Source (Heating Mode)	< 135,000 Btu/h (Cooling Capacity)	70°F Entering Water	3.5 COP		ARI 325
		50°F Entering Water		3.6 COP	ARI/ISO-13256-1
Ground Source (Heating Mode)	(Cooling Capacity)	32□F Entering Water	N/A	3.1 COP	ARI/ISO-13256-1

[a] IPLVs and Part load rating conditions are only applicable to equipment with capacity modulation.
[b] Deduct 0.2 from the required EERs and IPLVs for units with a heating section other than electric resistance heat.

Table B-9C– WATER CHILLING PACKAGES – MINIMUM EFFICIENCY REQUIREMENTS (TABLE 1-C3)

Equipment Type	Size Category	Efficiency prior to 10/29/2001	Efficiency as of 10/29/2001	Test Procedure
Air Cooled, With Condenser, Electrically Operated	< 150 Tons	2.70 COP 2.80 IPLV	2.80 COP 2.80 IPLV	ARI 550 or ARI 590 as appropriate
	≥150 Tons	2.50 COP 2.50 IPLV		
Air Cooled, Without Condenser, Electrically Operated	All Capacities	3.10 COP 3.20 IPLV	3.10 COP 3.10 IPLV	
Water Cooled, Electrically Operated, Positive Displacement (Reciprocating)	All Capacities	3.80 COP 3.90 IPLV	4.20 COP 4.65 IPLV	ARI 590
Water Cooled, Electrically Operated, Positive Displacement (Rotary Screw and Scroll)	< 150 Tons	3.80 COP 3.90 IPLV	4.45 COP 4.50 IPLV	ARI 550 or ARI 590 as appropriate
	≥150 Tons and < 300 Tons	4.20 COP 4.50 IPLV	4.90 COP 4.95 IPLV	
	≥300 Tons	5.20 COP 5.30 IPLV	5.50 COP 5.60 IPLV	
Water Cooled, Electrically Operated, Centrifugal	< 150 Tons	3.80 COP 3.90 IPLV	5.00 COP 5.00 IPLV	ARI 550
	≥150 Tons and < 300 Tons	4.20 COP 4.50 IPLV	5.55 COP 5.55 IPLV	
	≥300 Tons	5.20 COP 5.30 IPLV	6.10 COP 6.10 IPLV	
Air Cooled Absorption Single Effect	All Capacities	N/A	0.60 COP	ARI 560
Water Cooled Absorption Single Effect	All Capacities	N/A	0.70 COP	
Absorption Double Effect, Indirect-Fired	All Capacities	N/A N/A	1.00 COP 1.05 IPLV	
Absorption Double Effect, Direct-Fired	All Capacities	N/A N/A	1.00 COP 1.00 IPLV	

Table B-9D– PACKAGED TERMINAL AIR CONDITIONERS AND PACKAGED TERMINAL HEAT PUMPS – MINIMUM EFFICIENCY REQUIREMENTS (TABLE 1-C4)

Equipment Type	Size Category (Input)	Sub-Category or Rating Condition	Efficiency prior to 10/29/2001 [a]	Efficiency as of 10/29/2001[a]	Test Procedure
PTAC (Cooling Mode) New Construction	All Capacities	95°F db Outdoor Air	10.0 - (0.16 x Cap/1000)[a] EER	12.5 - (0.213 x Cap/1000)[a] EER	ARI 310/380
PTAC (Cooling Mode) Replacements[c]	All Capacities	95°F db Outdoor Air	10.0 - (0.16 x Cap/1000)[a] EER	10.9 - (0.213 x Cap/1000)[a] EER	
PTHP (Cooling Mode) New Construction	All Capacities	95°F db Outdoor Air	10.0 - (0.16 x Cap/1000)[a] EER	12.3 - (0.213 x Cap/1000)[a] EER	
PTHP (Cooling Mode) Replacements[c]	All Capacities	95°F db Outdoor Air	10.0 - (0.16 x Cap/1000)[a] EER	10.8 - (0.213 x Cap/1000)[a] EER	
PTHP (Heating Mode) New Construction	All Capacities		2.9 - (0.026 x Cap/1000)[a] COP	3.2 - (0.026 x Cap/1000)[a] COP	
PTHP (Heating Mode) Replacements[b]	All Capacities		2.9 - (0.026 x Cap/1000)[a] COP	2.9 - (0.026 x Cap/1000)[a] COP	

[a] Cap means the rated cooling capacity of the product in Btu/h. If the unit's capacity is less than 7000 Btu/h, use 7000 Btu/h in the calculation. If the unit's capacity is greater than 15,000 Btu/h, use 15,000 Btu/h in the calculation.
[B] Replacement units must be factory labeled as follows: "MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS." Replacement efficiencies apply only to units with existing sleeves less than 16-in. high and less than 42-in. wide.

Table B-9E– WARM AIR FURNACES AND COMBINATION WARM AIR FURNACES/AIR-CONDITIONING UNITS, WARM AIR DUCT FURNACES AND UNIT HEATERS – MINIMUM EFFICIENCY REQUIREMENTS (TABLE 1-C5)

Equipment Type	Size Category (Input)	Sub-Category or Rating Condition	Efficiency prior to 10/29/2001[a]	Efficiency as of 10/29/2001	Test Procedure
Warm Air Furnace, Gas-Fired	≥225,000 Btu/h (66 kW)	Maximum Capacity	80% E_t	80% E_c[b]	ANSI Z21.47
		Minimum Capacity[c]	78% E_t		
Warm Air Furnace, Oil-Fired	≥225,000 Btu/h (66 kW)	Maximum Capacity	81% E_t	81% E_t[a]	UL 727
		Minimum Capacity[c]	81% E_t	――	
Warm Air Duct Furnaces, Gas-Fired	All Capacities	Maximum Capacity	80% E_t	80% E_c[b]	ANSI Z83.9
		Minimum Capacity[c]	75% E_t	――	
Warm Air Unit Heaters, Gas-Fired	All Capacities	Maximum Capacity	80% E_t	80% E_c[b]	ANSI Z83.8
		Minimum Capacity[c]	74% E_t	――	
Warm Air Unit Heaters, Oil-Fired	All Capacities	Maximum Capacity	81% E_t	80% E_c[b]	UL 731
		Minimum Capacity[c]	81% E_t	――	

[a] E_t = Thermal efficiency. See test procedure for detailed discussion.
[b] E_c = Combustion efficiency (100% less flue losses). See test procedure for detailed discussion.
[c] Minimum ratings as provided for and allowed by unit's controls.

Table B-9F– BOILERS, GAS- AND OIL-FIRED – MINIMUM EFFICIENCY REQUIREMENTS (TABLE 1-C6)

Equipment Type[f]	Size Category	Sub-Category or Rating Condition	Efficiency prior to 10/29/2001[d]	Efficiency as of 10/29/2001	Test Procedure
Boilers, Gas-Fired	≥300,000 Btu/h	Maximum Capacity[a]	80% E_c [b]	75% E_t [c]	H.I. Htg Boiler Standard
		Minimum Capacity[a]	80% E_c [b]		
	> 2,500,000 Btu/h[e]	Hot Water	80% E_c [b]	80% E_c [b]	
	> 2,500,000 Btu/h[e]	Steam	80% E_c [b]	80% E_c [b]	
Boilers, Oil-Fired	≥300,000 Btu/h and ≤ 2,500,000 Btu/h	Maximum Capacity[a]	83% E_c [b]	78% E_t [c]	H.I. Htg Boiler Standard
		Minimum Capacity[a]	83% E_c [b]	——	
	> 2,500,000 Btu/h[e]	Hot Water	83% E_c [b]	83% E_c [b]	
	> 2,500,000 Btu/h[e]	Steam	83% E_c [b]	83% E_c [b]	
Oil-Fired (Residual)	≥300,000 Btu/h and ≤2,500,000 Btu/h	Maximum Capacity[a]	83% E_c [b]	78% E_t [c]	H.I. Htg Boiler Standard
		Minimum Capacity[a]	83% E_c [b]	——	
	> 2,500,000 Btu/h[e]	Hot Water	83% E_c [b]	83% E_c [b]	
	> 2,500,000 Btu/h[e]	Steam	83% E_c [b]	83% E_c [b]	

[a] Minimum and maximum ratings as provided for and allowed by the unit's controls.
[b] E_c = Combustion efficiency (100% less flue losses). See test procedure for detailed information.
[c] E_t = Thermal efficiency. See test procedure for detailed information.
[d] Alternate test procedures used at the manufacturer's option are ASME PTC-4.1 for units over 5,000,000 Btu/h input, or ANSI Z21.13 for units greater than or equal to 300,000 Btu/h and less than or equal to 2,500,000 Btu/h input.
[e] These requirements apply to boilers with rated input of 8,000,000 Btu/h or less that are not packaged boilers, and to all packaged boilers. minimum efficiency requirements for boilers cover all capacities of packaged boilers.

Table B-9G– PERFORMANCE REQUIREMENTS FOR HEAT REJECTION EQUIPMENT (TABLE 1-C7)

Equipment Type	Total System Heat Rejection Capacity at Rated Conditions	Sub-Category or Rating Condition	Performance Required as of 10/29/2001[a,b]	Test Procedure
Propeller or Axial Fan Cooling Towers	All	95°F Entering Water 85°F Leaving Water 78°F wb Outdoor Air	≥38.2 gpm/hp	CTI ATC-105 and CTI STD-201
Centrifugal Fan Cooling Towers	All	95°F Entering Water 85°F Leaving Water 78°F wb Outdoor Air	≥ 20.0 gpm/hp	CTI ATC-105 and CTI STD-201
Air Cooled Condensers	All	125°F Condensing Temperature R22 Test Fluid 190°F Entering Gas Temperature 15°F Subcooling 95°F Entering Drybulb	≥176,000 Btu/h·hp	ARI 460

[a] For purposes of this table, cooling tower performance is defined as the maximum flow rating of the tower divided by the fan nameplate rated motor power.
[b] For purposes of this table air-cooled condenser performance is defined as the heat rejected from the refrigerant divided by the fan nameplate rated motor power.

Table B-9H– COPS AND IPLVS FOR NON-STANDARD CENTRIFUGAL CHILLERS < 150 TONS (TABLE 1-C8)

Centrifugal Chillers < 150 Tons COP_{std} = 5.4								
			Condenser Flow Rate					
			2 gpm/ton	2.5 gpm/ton	3 gpm/ton	4 gpm/ton	5 gpm/ton	6 gpm/ton
Leaving Chilled Water Temperature (°F)	Entering Condenser Water Temperature (°F)	LIFT[a] (°F)	Required COP and IPLV (IPLV=COP)					
46	75	29	6.00	6.27	6.48	6.8	7.03	7.20
45	75	30	5.92	6.17	6.37	6.66	6.87	7.02
44	75	31	5.84	6.08	6.26	6.53	6.71	6.86
43	75	32	5.75	5.99	6.16	6.40	6.58	6.71
42	75	33	5.67	5.90	6.06	6.29	6.45	6.57
41	75	34	5.59	5.82	5.98	6.19	6.34	6.44
40	75	35	5.50	5.74	5.89	6.10	6.23	6.33
46	80	34	5.59	5.82	5.98	6.19	6.34	6.44
45	80	35	5.50	5.74	5.89	6.10	6.23	6.33
44	80	36	5.41	5.66	5.81	6.01	6.13	6.22
43	80	37	5.31	5.57	5.73	5.92	6.04	6.13
42	80	38	5.21	5.48	5.64	5.84	5.95	6.04
41	80	39	5.09	5.39	5.56	5.76	5.87	5.95
40	80	40	4.96	5.29	5.47	5.67	5.79	5.86
46	85	39	5.09	5.39	5.56	5.76	5.87	5.95
45	85	40	4.96	5.29	5.47	5.67	5.79	5.86
44	85	41	4.83	5.18	5.40	5.59	5.71	5.78
43	85	42	4.68	5.07	5.28	5.50	5.62	5.70
42	85	43	4.51	4.94	5.17	5.41	5.54	5.62
41	85	44	4.33	4.8	5.05	5.31	5.45	5.53
40	85	45	4.13	4.65	4.92	5.21	5.35	5.44
Condenser DT[b]			14.04	11.23	9.36	7.02	5.62	4.68

[a] LIFT = Entering Condenser Water Temperature – Leaving Chilled Water Temperature

[b] Condenser DT = Leaving Condenser Water Temperature (F) – Entering Condenser Water Temperature (F)

$K_{adj} = 6.1507 - 0.30244(X) + 0.0062692(X)^2 - 0.000045595(X)^3$

where X = Condenser DT + LIFT

$COP_{adj} = K_{adj} * COP_{std}$

Table B-9I– COPS AND IPLVS FOR NON-STANDARD CENTRIFUGAL CHILLERS > 150 TONS, ≤ 300 TONS (TABLE 1-C9)

Centrifugal Chillers > 150 Tons, ≤ 300 Tons COP_{std} = 5.55								
			Condenser Flow Rate					
			2 gpm/ton	2.5 gpm/ton	3 gpm/ton	4 gpm/ton	5 gpm/ton	6 gpm/ton
Leaving Chilled Water Temperature (°F)	Entering Condenser Water Temperature (°F)	LIFT[a] (°F)	Required COP and IPLV (IPLV=COP)					
46	75	29	6.17	6.44	6.66	6.99	7.23	7.40
45	75	30	6.08	6.34	6.54	6.84	7.06	7.22
44	75	31	6.00	6.24	6.43	6.71	6.9	7.05
43	75	32	5.91	6.15	6.33	6.58	6.76	6.89
42	75	33	5.83	6.07	6.23	6.47	6.63	6.75
41	75	34	5.74	5.98	6.14	6.36	6.51	6.62
40	75	35	5.65	5.90	6.05	6.26	6.40	6.51
46	80	34	5.74	5.98	6.14	6.36	6.51	6.62
45	80	35	5.65	5.90	6.05	6.26	6.40	6.51
44	80	36	5.56	5.81	5.97	6.17	6.30	6.40
43	80	37	5.46	5.73	5.89	6.08	6.21	6.30
42	80	38	5.35	5.64	5.80	6.00	6.12	6.20
41	80	39	5.23	5.54	5.71	5.91	6.03	6.11
40	80	40	5.10	5.44	5.62	5.83	5.95	6.03
46	85	39	5.23	5.54	5.71	5.91	6.03	6.11
45	85	40	5.10	5.44	5.62	5.83	5.95	6.03
44	85	41	4.96	5.33	**5.55**	5.74	5.86	5.94
43	85	42	4.81	5.21	5.42	5.66	5.78	5.86
42	85	43	4.63	5.08	5.31	5.56	5.69	5.77
41	85	44	4.45	4.93	5.19	5.46	5.60	5.69
40	85	45	4.24	4.77	5.06	5.35	5.50	5.59
Condenser DT[b]			14.04	11.23	9.36	7.02	5.62	4.68

[a] LIFT = Entering Condenser Water Temperature – Leaving Chilled Water Temperature

[b] Condenser DT = Leaving Condenser Water Temperature (F) - Entering Condenser Water Temperature (F)

$K_{adj} = 6.1507 - 0.30244(X) + 0.0062692(X)^2 - 0.000045595(X)^3$

where X = Condenser DT + LIFT

$COP_{adj} = K_{adj} * COP_{std}$

Table B-9J– COPS AND IPLVS FOR NON-STANDARD CENTRIFUGAL CHILLERS > 300 TONS (TABLE 1-C10)

Centrifugal Chillers > 300 Tons COP_{std} = 6.1								
			Condenser Flow Rate					
			2 gpm/ton	2.5 gpm/ton	3 gpm/ton	4 gpm/ton	5 gpm/ton	6 gpm/ton
Leaving Chilled Water Temperature (°F)	Entering Condenser Water Temperature (°F)	LIFT[a] (°F)	Required COP and IPLV (IPLV=COP)					
46	75	29	6.80	7.11	7.35	7.71	7.97	8.16
45	75	30	6.71	6.99	7.21	7.55	7.78	7.96
44	75	31	6.61	6.89	7.09	7.40	7.61	7.77
43	75	32	6.52	6.79	6.98	7.26	7.45	7.60
42	75	33	6.43	6.69	6.87	7.13	7.31	7.44
41	75	34	6.33	6.60	6.77	7.02	7.18	7.30
40	75	35	6.23	6.50	6.68	6.91	7.06	7.17
46	80	34	6.33	6.60	6.77	7.02	7.18	7.30
45	80	35	6.23	6.50	6.68	6.91	7.06	7.17
44	80	36	6.13	6.41	6.58	6.81	6.95	7.05
43	80	37	6.02	6.31	6.49	6.71	6.85	6.94
42	80	38	5.90	6.21	6.40	6.61	6.75	6.84
41	80	39	5.77	6.11	6.30	6.52	6.65	6.74
40	80	40	5.63	6.00	6.20	6.43	6.56	6.65
46	85	39	5.77	6.11	6.30	6.52	6.65	6.74
45	85	40	5.63	6.00	6.20	6.43	6.56	6.65
44	85	41	5.47	5.87	**6.10**	6.33	6.47	6.55
43	85	42	5.30	5.74	5.98	6.24	6.37	6.46
42	85	43	5.11	5.60	5.86	6.13	6.28	6.37
41	85	44	4.90	5.44	5.72	6.02	6.17	6.27
40	85	45	4.68	5.26	5.58	5.90	6.07	6.17
Condenser DT[b]			14.04	11.23	9.36	7.02	5.62	4.68

[a] LIFT = Entering Condenser Water Temperature – Leaving Chilled Water Temperature

[b] Condenser DT = Leaving Condenser Water Temperature (F) - Entering Condenser Water Temperature (F)

K_{adj} = 6.1507 - 0.30244(X) + 0.0062692$(X)^2$ - 0.000045595$(X)^3$

where X = Condenser DT + LIFT

$COP_{adj} = K_{adj} * COP_{std}$

Table B-9K– MINIMUM EFFICIENCY REQUIREMENTS FOR WATER HEATING EQUIPMENT (TABLE 1-C11)

Equipment Type	Size Category	Sub-Category or Rating Condition	Performance Required prior to 10/29/2001[a, b]	Performance Required as of 10/29/2001[b]	Test Procedure
Gas Storage Water Heaters	> 75,000 Btu/h and ≤ 155,000 Btu/h	< 4,000 Btu/h/gal	78% E_t 7.47V + 655 SL, Btu/h	80% E_t (Q/800 + 110√V) SL, Btu/h	ANSI Z21.10.3
	> 155,000 Btu/h	< 4,000 Btu/h/gal	78% E_t 7.47V + 546 SL, Btu/h	80% E_t (Q/800 + 110√V)SL, Btu/h	
Gas Instantaneous Water Heaters	> 200,000 Btu/h[c]	≥ 4,000 Btu/h/gal and < 10 gal	80% E_t	80% E_t	ANSI Z21.10.3
	> 200,000 Btu/h[C]	≥ 4,000 Btu/h/gal and ≥ 10 gal	77% E_t 13.22V + 385 SL, Btu/h	80% E_t (Q/800 + 110√V) SL, Btu/h	
Oil Storage Water Heaters	> 105,000 Btu/h and ≤ 155,000 Btu/h	< 4,000 Btu/h/gal	78% E_t 7.47V + 655 SL, Btu/h	78% E_t (Q/800 + 110√V) SL, Btu/h	ANSI Z21.10.3
	> 155,000 Btu/h	< 4,000 Btu/h/gal	78% E_t 7.47V + 546 SL, Btu/h	78% E_t (Q/800 + 110√V) SL, Btu/h	
Oil Instantaneous Water Heaters	> 210,000 Btu/h[c]	≥ 4,000 Btu/h/gal and < 10 gal	80% E_t	80% E_t	ANSI Z21.10.3
	> 210,000 Btu/h[c]	≥ 4,000 Btu/h/gal and ≥ 10 gal	77% E_t 13.22V + 385 SL, Btu/h	78% E_t (Q/800 + 110√V) SL, Btu/h	

[a] Thermal efficiency (E_t) is a minimum requirements, while standby loss (SL) is a maximum Btu/h based on a nominal 70°F temperature difference between stored water and ambient requirements. In the EF equation, V is the rated volume in gallons. In the SL equation, V is the measured volume in gallons.

[b] Thermal efficiency (E_t) is a minimum requirements, while standby loss (SL) is a maximum Btu/h based on a 70° temperature difference between stored water and ambient requirements. In the EF equation, V is the rated volume in gallons. In the SL equation, V is the rated volume in gallons and Q is the nameplate input rate in Btu/h.

[c] Instantaneous water heaters with input rates below 200,000 Btu/hmust comply with these requirements if the water heater is designed to heat water to temperatures 180°F or higher.

Table B-10A–Illuminance Categories

NOTE: This table is taken from the *Office Lighting American National Standard Practice*, ANSI/IES RP-1, 1993. The table is produced in its entirely, including captions and footnotes. Permission to reprint is pending.

TABLE 3: Currently recommended illuminance categories for lighting design --target maintained values (See Table 4 for Illuminance Values). These recommendations provide a guide for efficient visual performance in office spaces rather than for safety alone. For a tabulation of minimum levels of illumination required for safety, see Table 7.

	Illuminance Category	Veiling Reflectance
Accounting		
(see individual tasks)		
Copied Tasks		
Ditto Copy (6)	E	!
Micro-fiche reader (1)	B	!!
Mimeograph	D	
Photographs, mod. detail	E	!!
Thermal copy, poor copy	F	!
Xerography, 3rd generation (6) and greater	E	
Xerograph	D	
Drafting Tasks		
Drafting: Mylar		
High contrast media; India ink, plastic leads, soft graphite leads	E	!
Low contrast media, hard graphite leads	F	!
Vellum: high contrast	E	!
low contrast	F	
Tracing paper: high contrast	E	!
low contrast	F	
Overlays (2)		
Light Table	C	
Prints: Blue Line	E	
Blueprints	E	
Sepia prints	F	
EDP Tasks		
CRT Screens (1)	B	!!
Impact printer: good ribbon	D	
poor ribbon (6)	E	
2nd carbon and greater (6)	E	
Ink jet printer	D	
Keyboard reading	D	
Machine rooms: active operations	D	
tape storage	D	
machine area	C	
equipement service (3)	E	
Thermal print	E	!
Filing		
(see individual tasks)		
General and Public Areas		
AV areas	D	
Conference rooms	D	
(critical seeing, refer to individual tasks)		
Display areas (4)	C	
Duplicating and off-set printing area	D	
Elevators	C	
Escalators	C	
First aid areas	E	
Food service (7)		
Hallways	B	
Janitorial spaces	C	
Libraries (7)		
Lobbies and lounges	C	
Model making	F	
Mail sorting	E	
Mechanical rooms: operation	B	
equipment service (3)	E	
Reception area	C	
Rest rooms	C	
Stairs	B	
Utility rooms	B	
Graphic Design and Material		
Color selection (5)	F	

Charting and mapping	F	
Graphs	E	
Keylining	F	
Layout and artwork	F	
Photographs, mod. detail	E	!!
Handwritten Tasks		
#2 pencil and softer leads	D	!
#3 pencil	E	!
#4 pencil and harder leads (6)	F	!
Ball-point pen	D	!
Felt-tip pen	D	
Handwritten carbon copies (6)	E	
Non photographically reproducible colors	F	
Printed Tasks		
6 pt (6) see 2.4	E	!
8 & 10 pt	D	!
Glossy magazines	D	!!
Maps	E	
Newsprint	D	
Typed Originals	D	
Typed 2nd carbon and later (6)	E	
Telephone books	E	

NOTES:

1. Veiling reflections may be produced on glass surfaces. It may be necessary to treat plus weighting factors as minus in order to obtain proper light balance.
2. Degradation factors: Overlays--add 1 weighing factor for each overlay
   Used material--estimate additional factors
   See Table 4
3. Only when actual equipment service is in progress. May be achieved by a general lighting system or by localized lighting or by portable equipment.
4. For details on the lighting of display refer to Recommended Practice for Lighting Merchandise Areas. (10)
5. For color matching, the quality of the color of the light source may be important.
6. Designing to higher levels to accommodate poor quality tasks should be undertaken only after it is determined that task quality cannot be improved. If a poor quality task cannot be eliminated, its "time-and-importance" factor should be carefully considered before allowing it to govern the illuminance level selection.
7. See Reference 9.

! Task subject to veiling reflections. Illuminance listed is not an ESI value. Currently, insufficient experience in the use of ESI target values precludes the direct use of Equivalent Sphere Illumination in the present consensus approach recommend illuminance values. Equivalent Sphere Illumination may be used as a tool in determining the effectiveness of controlling veiling reflections and as part of the evaluation of lighting systems.

!! Especially subject to veiling reflectances. It may be necessary to shield the task or to reorient it.

Definition of Merchandising and Associated Service Areas in Stores

NOTE: This table is taken from the *Recommended Practice for Lighting Merchandising Areas*, IES RP-2. The table is produced in its entirety, including captions and footnotes. Permission to reprint is pending.

Table B-10B–Currently Recommended Illuminance for Lighting Design in Merchandising and Associated Areas -- Target Maintained Levels

Areas or Tasks	Description	Type of Activity Area*	Lux	Foot-candles
Circulation	Area not used for display or appraisal of merchandise for sales transactions	High activity Medium activity Low activity	300 400 100	30 20 10
Merchandise*** (including showcases & wall displays)	That plane area, horizontal to vertical, where merchandise is displayed and readily accessible for customer examination	High activity Medium activity Low activity	1000 750 300	100 75 30
Show windows				
Daytime lighting				
General			2000	200
Feature			10000	1000
Nighttime lighting				
Main business districts-highly competitive				
General			2000	200
Feature			10000	1000
Secondary business districts or small towns				
General			1000	100
Feature			5000	500
Sales Transactions	Areas used for employee price verification and for recording transactions	Reading of copied, written, printed or EDP information	See Table 2	
Support Services	Store spaces where merchandising is a prime consideration	Alteration fitting stock, wrapping and packaging rooms	See Table 2	

NOTES:

* One store may encompass all three types within the building: High Activity area -- where merchandise displayed has recognizable usage. Evaluation and viewing time is rapid, and merchandise is sown to attract and stimulate the impulse buying decision; Medium Activity -- where merchandise is familiar in type or usage, but the customer may require time and/or help in evaluation of quality, usage, or for the decision to buy; and Low Activity -- where merchandise is displayed that is purchased less frequently by the customer, who may be unfamiliar with the inherent quality, design, value or usage. Where assistance and time is necessary to reach a buying decision.

** Maintained on the task or in the area at any time.

*** Lighting levels to be maintained in the plane of the merchandise.

Fig. 2-1–Currently Recommended Illuminance Categories and Illuminance Values for Lighting Design -Targeted Maintenance Levels

The tabulation that follows is a consolidated listing of the Society's current illuminance recommendations. This listing is intended to guide the lighting designer in selecting an appropriate illuminance for design and evaluation of lighting systems.

Guidance is provided in two forms: (1), in Parts I, II and III as an *Illuminance Category*, representing a range of illuminances (see page 2-3 for a method of selecting a value within each illuminance range); and (2), in parts IV, V and VI as an *Illuminance Value*. Illuminance Values are given in *lux* with an approximate equivalence in footcandles and as such are intended as *target* (nominal) values with deviations expected. These target values also represent maintained values (see page 2-23).

This table has been divided into the six parts for ease of use. Part I provides a listing of both Illuminance Categories and Illuminance Values for generic types of interior activities and normally is to be used when Illuminance Categories for a specific Area/Activity cannot be found in parts II and III. Parts IV, V and VI provide target maintained Illuminance Values for outdoor facilities sports and recreational areas, and transportation vehicles where special considerations apply as discussed on page 2-4.

In all cases the recommendations in this table are based on the assumption that the lighting will be properly designed to take into account the visual characteristics of the task. See the design information in the particular application sections in this Application Handbook for further recommendations.

Table B-10C–Illuminance Categories (Commercial, Institutional, Residential and Public Assembly Interiors)

NOTE: This table is taken from the Figure 2-2 of the IES Lighting Handbook 1982 Application Volume. Part II of the table is produced in its entirety, with captions and footnotes.

Area/Activity	Illuminance Category
Accounting (see **Reading**)	
Air terminals (see Transportation terminals)	
Armories	C[1]
Art galleries (see **Museums**)	
Auditoriums	
Assembly	C[1]
Social activity	B
Banks	
Lobby	
General	C
Writing area	D
Tellers' stations	E[3]
Barber shops and beauty parlors	E
Churches and synagogues	(see page 7-2)[4]
Club and lodge rooms	
Lounge and reading	D
Conference rooms	
Conferring	D
Critical seeing (refer to individual task)	
Court rooms	
Seating area	C
Court activity area	E[3]
Dance halls and discotheques	B
Study halls (see **Reading**)	
Typing (see **Reading**)	
Sports facilities (see Part V, Sports and	
Recreational Areas)	
Cafeterias (see **Food service facilities**)	
Dormitories (see **Residences**)	
Elevator, freight and passenger	C
Exhibition halls	C[1]
Filing (refer to individual task)	

Financial facilities (see **Banks**)	
Fire halls (see **Municipal buildings**)	
Food service facilities	
Dining areas	
Cashier	D
Cleaning	C
Dining	B[6]
Food displays (see **Merchandising spaces**)	
Kitchen	E
Garages -- parking (see page 14-28)	
Gasoline stations (see **Service stations**)	
Graphic design and material	
Color selection	F[11]
Charting and mapping	F
Graphs	E
Keylining	F
Layout and artwork	F
Photographs, moderate detail	E[13]
Health care facilities	
Ambulance (local)	E
Anesthetizing	E
Autopsy and morgue[17, 18]	
Autopsy, general	E
Autopsy table	G
Morgue, general	D
Museum	E
Cardiac function lab	E
Central sterile supply	
Inspection, general	E
Inspection	F
At sinks	E
Work areas, general	D
Processed storage	D
Corridors[17]	
Nursing areas -- day	C
Nursing areas -- night	B
Operating areas, delivery, recovery,	
and laboratory suites and service	E
Critical care areas[17]	
General	C
Examination	E
Surgical task lighting	H
Hand washing	F
Cystoscopy room [17,18]	
Dental suite [17]	
General	D
Instrument tray	E
Oral Cavity	H
Prosthetic laboratory, general	D
Prosthetic laboratory, work bench	E
Prosthetic, laboratory, local	F
Recovery room, general	C

Recovery room, emergency	
examination	E
Dialysis unit, medical[17]	F
Elevators	C
EKG and specimen room[17]	
General	B
On equipment	C
Emergency outpatient[17]	
General	E
Local	F
Endoscopy rooms [17, 18]	
General	E
Peritoneoscopy	D
Culdoscopy	D
Examination and treatment rooms [17]	
General	D
Local	E
Eye surgery[17, 18]	F
Fracture room[17]	
General	E
Local	F
Inhalation therapy	D
Laboratories[17]	
Specimen collecting	E
Tissue laboratories	F
Microscopic reading room	D
Gross specimen review	F
Chemistry rooms	E
Bacteriology rooms	
General	E
Reading culture plates	F
Hematology	E
Linens	
Sorting soiled linen	D
Central (clean) linen room	D
Sewing room, general	D
Sewing room, work area	E
Linen closet	B
Lobby	C
Locker rooms	C
Medical illustration studio[17, 18]	F
Medical records	E
Nurseries[17]	
General[18]	C
Observation and treatment	E
Nursing stations[17]	
General	D
Desk	E
Corridors, day	C
Corridors, night	A
Medication station	E
Obstetric delivery suite[17]	
Labor rooms	
General	C
Local	E
Birthing room	F
Delivery area	
Scrub, general	F
General	G
Delivery table	(see page 7-19)

Resuscitation	G
Post delivery recovery area	E
Substerilizing room	B
Occupational therapy[17]	
Work area, general	D
Work tables or benches	E
Patients' rooms[17]	
General[18]	B
Observation	A
Critical examination	E
Reading	D
Toilets	D
Pharmacy[17]	
General	E
Alcohol vault	D
Laminar flow bench	F
Night light	A
Parenteral solution room	D
Physical therapy departments	
Gymnasiums	D
Tank rooms	D
Treatment cubicles	D
Postanesthetic recovery room[17]	
General[18]	E
Local	H
Pulmonary function laboratories[17]	E
Radiological suite[17]	
Diagnostic section	
General[18]	A
Waiting area	A
Radiographic/fluoroscopic room	A
Film sorting	F
Barium kitchen	E
Radiation therapy section	
General[18]	B
Waiting area	B
Isotope kitchen, general	E
Isotope kitchen, benches	E
Computerized radiotomography section	
Scanning room	B
Equipment maintenance room	E
Solarium	
General	C
Local for reading	D
Stairways	C
Surgical suite[17]	
Operating room, general[18]	F
Operating table	(see page 7-15)
Scrub room	F
Instruments and sterile supply room	D
Clean up room, instruments	E
Anesthesia	C
Substerilizing room	C
Surgical induction room[17, 18]	E
Surgical holding area[17, 18]	E
Toilets	C
Utility room	D
Waiting areas[17]	
General	C
Local for reading	D
Homes (see **Residences**)	
Hospitality facilities	

(see **Hotels, food service facilities**)	
Hospitals (see **Health care facilities**)	
Hotels	
Bathrooms, for grooming	D
Bedrooms, for reading	D
Corridors, elevators and stairs	C
Front desk	E[3]
Linen room	
Sewing	F
General	C
Lobby	
General lighting	C
Reading and working areas	D
Canopy (see Part IV, Outdoor Facilities)	
Houses of worship	(see page 7-5)
Kitchens (see **Food service facilities** or **Residences**)	
Libraries	
Reading areas (see **Reading**)	
Libraries	
Book stacks [vertical 760 millimeters	
(30 inches) above floor]	
Active stacks	D
Inactive stacks	B
Book repair and binding	D
Cataloging	D[3]
Card files	E
Carrels, individual study areas	
(see **Reading**) Circulation desks	D
Map, picture and print rooms (see **Graphic design**	
and material)	
Audiovisual areas	D
Audio listening areas	D
Microform areas (see **Reading**)	
Locker rooms	C
Merchandising spaces	
Alteration room	F
Fitting room	
Dressing areas	D
Fitting areas	F
Locker rooms	C
Stock rooms, wrapping and packaging	D
Sales transaction area (see **Reading**)	
Circulating	(see page 8-7)[8]
Merchandise	(see page 8-7)[8]
Feature display	(see page 8-7)[8]
Show windows	(see page 8-7)[8]
Motels (see **Hotels**)	
Municipal buildings -- fire and police	
Police	
Identification records	F
Jail cells and interrogation rooms	D
Fire hall	D
Museums	
Displays of non-sensitive materials	D
Displays of sensitive materials	(see page 7-34)[2]
Lobbies, general gallery areas, corridors	C

Restoration or conservation shops	
and laboratories	E
Nursing homes (see **Health care facilities**)	
Offices	
Accounting (see **Reading**)	
Audio-visual areas	D
Conference areas (see **Conference rooms**)	
Drafting (see **Drafting**)	
General and private offices (see **Reading**)	
Libraries (see **Libraries**)	
Lobbies, lounges and reception areas	C
Mail sorting	E
Off-set printing and duplicating area	D
Spaces with VDTs (see page 5-13)	
Parking facilities (see page 14-28)	
Post offices (see **Offices**)	
Reading	
Copied tasks	
Ditto copy	E[3]
Micro-fiche reader	B[12, 13]
Mimeograph	D
Photograph, moderate detail	E[13]
Thermal copy, poor copy	F[3]
Xerography	D
Xerography, 3rd generation and	
greater	E
Electronic data processing tasks	
CRT screens	B[12, 13]
Impact printer	
good ribbon	D
poor ribbon	E
2nd carbon and greater	E
Ink jet printer	D
Keyboard reading	D
Machine rooms	
Active operations	D
Tape storage	D
Machine area	C
Equipment service	E[10]
Thermal print	E
Handwritten tasks	
#2 pencil and softer leads	D[3]
#3 pencil	E[3]
#4 pencil and harder leads	F[3]
Ball-point pen	D[3]
Felt-tip pen	D
Handwritten carbon copies	E
Non photographically reproducible colors	F
Chalkboards	E[3]
Printed tasks	
6 point type	E[3]
8 and 10 point type	D[3]
Glossy magazines	D[13]
Maps	E
Newsprint	D
Typed originals	D
Typed 2nd carbon and later	E
Telephone books	E

Residences	
General lighting	
Conversation, relaxation and entertainment	B
Passage areas	B
Specific visual tasks[20]	
Dining	C
Grooming	
Makeup and shaving	D
Full-length mirror	D
Handcrafts and hobbies	
Workbench hobbies	
Ordinary tasks	D
Difficult tasks	E
Critical tasks	F
Easel hobbies	E
Ironing	D
Kitchen duties	
Kitchen counter	
Critical seeing	E
Noncritical	D
Kitchen range	
Difficult seeing	E
Noncritical	D
Kitchen sink	
Difficult seeing	E
Noncritical	D
Laundry	
Preparation and tubs	D
Washer and dryer	D
Music study (piano or organ)	
Simple scores	D
Advanced scores	E
Substandard size scores	F
Reading	
In a chair	
Books, magazines and newspapers	D
Handwriting, reproductions and	
poor copies	E
In bed	
Normal	D
Prolonged serious or critical	E
Desk	
Primary task plane, casual	D
Primary task plane, study	E
Sewing	
Hand sewing	
Dark fabrics, low contrast	F
Light to medium fabrics	E
Occasional, high contrast	D
Machine sewing	
Dark fabrics, low contrast	F
Light to medium fabrics	E
Occasional, high contrast	D
Table games	D
Restaurants (see **Food service facilities**)	
Safety	(see page 2-45)
Schools (see **Educational facilities**)	
Service spaces (see also **Storage rooms**)	
Stairways, corridors	C
Elevators, freight and passenger	C
Toilet and washroom	C

Service stations	
Service bays (see Part III, Industrial Group)	
Sales room (see **Merchandising spaces**)	
Show windows	(see page 8-7)
Stairways (see **Service spaces**)	
Storage rooms (see Part III, Industrial Group)	
Stores (see **Merchandising spaces** and **Show windows**)	
Television	(see Section 11)
Theater and motion picture houses	(see Section 11)
Toilets and washrooms	C
Transportation terminals	
Waiting room and lounge	C
Ticket counters	E
Baggage checking	D
Rest rooms	C
Concourse	B
Boarding area	C

Notes:

[1]Include provisions for higher levels for exhibitions.

[2]Specific limits are provided to minimize deterioration effects.

[3]Task subject to veiling reflections. Illuminance listed is not an Equivalent Sphere Illumination (ESI) value. Currently, insufficient experience in the use of ESI target values precludes the direct use of ESI in the present consensus approach to recommend illuminance values. ESI may be used as a tool in determining the effectiveness of controlling veiling reflections and as a part of the evaluation of lighting systems.

[4]Illuminance values are listed based on experience and consensus. Values relate to needs during various religious ceremonies.

[5]Degradation factors: Overlays -- add 2 weighting factor for each overlay; Used material -- estimate additional factors.

[6]Provide higher level over food service or selection areas.

[7]Supplementary illumination as in delivery room must be available.

8Illuminance values developed for various degrees of store area activity.

[9]Or not less than 1/5 the level in the adjacent areas.

[10]Only when actual equipment service is in process. May be achieved by a general lighting system or by localized or portable equipment.

[11]For color matching, the spectral quality of the color of the light source is important.

[12]Veiling reflections may be produced on glass surfaces. It may be necessary to treat plus weighting factors as minus in order to obtain proper illuminance.

[13]Especially subject to veiling reflections. It may be necessary to shield the task or to reorient it.

[14]Vertical

[15]Illuminance values may vary widely, depending upon the effect desired, the decorative scheme, and the use made of the room.

[16]Supplementary lighting should be provided in this space to produce the higher levels required for specific seeing tasks involved.

[17]Good to high color rendering capability should be considered in these areas. As lamps of higher luminous efficacy and higher color rendering capability become available and economically feasible, they should be applied in all areas of health care facilities.

[18]Variable (dimming or switching).

[19]Values based on a 25 percent reflectance, which is average for vegetation and typical outdoor surfaces. These figures must be adjusted to specific reflectances of materials lighted for equivalent brightness. Levels give satisfactory brightness patterns when viewed from dimly lighted terraces or interiors. When viewed from dark areas they may be reduced by at least 1/2; or they may be doubled when a high key is desired.

[20]General lighting should not be less than 1/3 of visual task illuminance nor less than 200 lux [20 footcandles].

[21]Industry representatives have established a table of single illuminance values which, in their opinion, can be used in preference to employing reference 6. Illuminance values for specific operations can also be determined using illuminance categories of similar tasks and activities found in this table and the application of the appropriate weighting factors in Fig. 2-3.

[22]Special lighting such that (1) the luminous area is large enough to cover the surface, which is being inspected and (2) the luminance is within the limits necessary to obtain comfortable contrast conditions. This involves the use of sources of large area and relatively low luminance in which the source luminance is the principal factor rather than the illuminance produced at a given point.

[23]Maximum levels -- controlled system.

[24]Additional lighting needs to be provided for maintenance only.

[25]Color temperature of the light source is important for color matching.

[26] Select upper level for high speed conveyor systems. For grading redwood lumber 3000 lux [300 footcandles] is required.

[27]Higher levels from local lighting may be required for manually operated cutting machines.

[28]If color matching is critical, use illuminance category G.

LUMINAIRE POWER

Lamp No.	Lamp Designation	Ballast No.	Ballast Abbreviation	Ballast Description	Watts/ Luminaire	Comments
Fluorescent Circline						
Fluorescent Circline, Rapid Start (22 W)						
1	FC8T9	1	MAG STD	Magnetic Standard	27	8" OD
Fluorescent Circline, Rapid Start (32 W)						
1	FC12T9	1	MAG STD	Magnetic Standard	45	12" OD
Fluorescent Circline, Rapid Start (40 W)						
1	FC16T9	1	MAG STD	Magnetic Standard	57	16" OD
Fluorescent 2D						
Compact Fluorescent 2D (10W, GR10q-4 Four Pin Base)						
1	CFS10W/GR10q	1	MAG STD	Magnetic Standard	16	3.6" across
1	CFS10W/GR10q	1	ELECT	Electronic	13	
2	CFS10W/GR10q	1	ELECT	Electronic	26	
Compact Fluorescent 2D (16W, GR10q-4 Four Pin Base)						
1	CFS16W/GR10q	1	MAG STD	Magnetic Standard	23	5.5" across
1	CFS16W/GR10q	1	ELECT	Electronic	15	
2	CFS16W/GR10q	1	ELECT	Electronic	30	
Compact Fluorescent 2D (21W, GR10q-4 Four Pin Base)						
1	CFS21W/GR10q	1	MAG STD	Magnetic Standard	31	5.5" across
1	CFS21W/GR10q	1	ELECT	Electronic	21	
2	CFS21W/GR10q	1	ELECT	Electronic	42	
Compact Fluorescent 2D (28W, GR10q-4 Four Pin Base)						
1	CFS28W/GR10q	1	MAG STD	Magnetic Standard	38	8.1" across
1	CFS28W/GR10q	1	ELECT	Electronic	28	
2	CFS28W/GR10q	1	ELECT	Electronic	56	
Compact Fluorescent 2D (38W, GR10q-4 Four Pin Base)						
1	CFS38W/GR10q	1	ELECT	Electronic	37	8.1" across
2	CFS38W/GR10q	1	ELECT	Electronic	74	
Compact Fluorescent Twin (5 W, G23 Two Pin Base - F5TT Lamp)						
1	CFT5W/G23	1	MAG STD	Magnetic Standard	9	4.1" MOL
2	CFT5W/G23	2	MAG STD	Magnetic Standard	18	
Compact Fluorescent Twin (7 W, G23 Two Pin Base - F7TT Lamp)						
1	CFT7W/G23	1	MAG STD	Magnetic Standard	11	5.3" MOL
2	CFT7W/G23	2	MAG STD	Magnetic Standard	22	

Table B-11–Luminaire Power (continued)

LUMINAIRE POWER

Lamp		Ballast			Watts/	
No.	Designation	No.	Abbreviation	Description	Luminaire	Comments
Compact Fluorescent Twin (9 W, G23 Two Pin Base - F9TT Lamp)						
1	CFT9W/G23	1	MAG STD	Magnetic Standard	13	6.5" MOL
2	CFT9W/G23	2	MAG STD	Magnetic Standard	26	
Compact Fluorescent Twin (13 W, GX23 Two Pin Base - F13TT)						
1	CFT13W/GX23	1	MAG STD	Magnetic Standard	17	7.5" MOL
2	CFT13W/GX23	2	MAG STD	Magnetic Standard	34	
Compact Fluorescent Quad (9 W, G23-2 Two Pin Base - F9DTT Lamp)						
1	CFQ9W/G23-2	1	MAG STD 120	120 V Magnetic Standard	13	4.4" MOL
2	CFQ9W/G23-2	2	MAG STD 120	120 V Magnetic Standard	26	
Compact Fluorescent Quad (13 W, G24d-1 Two Pin Base - F13DTT Lamp)						
1	CFQ13W/G24d-1	1	MAG STD 120	120 V Magnetic Standard	18	6.0" MOL
2	CFQ13W/G24d-1	2	MAG STD 120	120 V Magnetic Standard	36	
1	CFQ13W/G24d-1	1	MAG STD 277	227 V Magnetic Standard	16	
2	CFQ13W/G24d-1	2	MAG STD 277	227 V Magnetic Standard	32	
Compact Fluorescent Quad (13 W, GX23-2 Two Pin Base)						
1	CFQ13W/GX23-2	1	MAG STD	Magnetic Standard	17	4.8" MOL
2	CFQ13W/GX23-2	2	MAG STD	Magnetic Standard	34	
Compact Fluorescent Quad (16W GX32d-1 Two Pin Base)						
1	CFQ16W/GX32d-1	1	MAG STD	Magnetic Standard	20	5.5" MOL
2	CFQ16W/GX32d-1	2	MAG STD	Magnetic Standard	40	
Compact Fluorescent Quad (18 W, G24d-2 Two Pin Base - F18DTT Lamp)						
1	CFQ18W/G24d-2	1	MAG STD 120	120 V Magnetic Standard	25	6.8" MOL
2	CFQ18W/G24d-2	2	MAG STD 120	120 V Magnetic Standard	50	
1	CFQ18W/G24d-2	1	MAG STD 277	227 V Magnetic Standard	22	
2	CFQ18W/G24d-2	2	MAG STD 277	227 V Magnetic Standard	44	
Compact Fluorescent Quad (22W, GX32d Two Pin Base)						
1	CFQ22W/GX32d-2	1	MAG STD	Magnetic Standard	27	6.0" MOL
2	CFQ22W/GX32d-2	2	MAG STD	Magnetic Standard	54	
Compact Fluorescent Quad (26 W, G24d-3 Two Pin Base - F26DTT Lamp)						
1	CFQ26W/G24d-3	1	MAG STD 120	120 V Magnetic Standard	37	7.6" MOL
2	CFQ26W/G24d-3	2	MAG STD 120	120 V Magnetic Standard	74	
1	CFQ26W/G24d-3	1	MAG STD 277	227 V Magnetic Standard	33	
2	CFQ26W/G24d-3	2	MAG STD 277	227 V Magnetic Standard	66	
1	CFQ26W/G24d-3	1	ELECT 277V	277 V Electronic	27	
2	CFQ26W/G24d-3	2	ELECT 277V	277 V Electronic	54	

LUMINAIRE POWER

Lamp		Ballast			Watts/ Luminaire	Comments
No.	Designation	No.	Abbreviation	Description		
Compact Fluorescent Quad (28W GX32d Two Pin Base)						
1	CFQ28W/GX32d-3	1	MAG STD	Magnetic Standard	34	6.8" MOL
2	CFQ28W/GX32d-3	2	MAG STD	Magnetic Standard	68	
Compact Fluorescent Quad (10 W, G24q-1 Four Pin Base)						
1	CFQ10W/G24q-1	1	MAG STD 120	120 V Magnetic Standard	16	4.6" MOL
2	CFQ10W/G24q-1	2	MAG STD 120	120 V Magnetic Standard	32	
1	CFQ10W/G24q-1	1	MAG STD 277	227 V Magnetic Standard	13	
2	CFQ10W/G24q-1	2	MAG STD 277	227 V Magnetic Standard	26	
Compact Fluorescent Quad (13 W, G24q-1 Four Pin Base)						
1	CFQ13W/G24q-1	1	MAG STD 120	120 V Magnetic Standard	18	6.0" MOL
2	CFQ13W/G24q-1	2	MAG STD 120	120 V Magnetic Standard	36	
1	CFQ13W/G24q-1	1	MAG STD 277	227 V Magnetic Standard	16	
2	CFQ13W/G24q-1	2	MAG STD 277	227 V Magnetic Standard	32	
Compact Fluorescent Quad (13 W, GX7 Four Pin Base)						
1	CFQ13W/GX7	1	MAG STD	Magnetic Standard	17	4.8" MOL
2	CFQ13W/GX7	2	MAG STD	Magnetic Standard	34	
Compact Fluorescent Quad (18 W, G24q-2 Four Pin Base)						
1	CFQ18W/G24q-2	1	MAG STD 120	120 V Magnetic Standard	25	6.8" MOL
2	CFQ18W/G24q-2	2	MAG STD 120	120 V Magnetic Standard	50	
1	CFQ18W/G24q-2	1	MAG STD 277	227 V Magnetic Standard	22	
2	CFQ18W/G24q-2	2	MAG STD 277	227 V Magnetic Standard	44	
Compact Fluorescent Triple (13 W, GX24q-1 Four Pin Base)						
1	CFM 13W/GX24q-1	1	MAG STD	Magnetic Standard	18	4.2" MOL
2	CFM 13W/GX24q-1	2	MAG STD	Magnetic Standard	36	
Compact Fluorescent Triple (18W, GX24q-2 Four Pin Base)						
1	CFM 18W/GX24q-2	1	MAG STD	Magnetic Standard	25	5.0" MOL
2	CFM 18W/GX24q-2	2	MAG STD	Magnetic Standard	50	
Compact Fluorescent Triple (26W, GX24q-3 Four Pin Base)						
1	CFM 26W/GX24q-3	1	MAG STD	Magnetic Standard	37	4.9 to 5.4" MOL
2	CFM 26W/GX24q-3	2	MAG STD	Magnetic Standard	74	

LUMINAIRE POWER

Lamp No.	Lamp Designation	Ballast No.	Ballast Abbreviation	Ballast Description	Watts/ Luminaire	Comments
Fluorescent Twin (18W - F18TT Lamp)						
1	FT18W/2G11	1	MAG EE	Magnetic Energy Efficient	23	
2	FT18W/2G11	1	MAG EE	Magnetic Energy Efficient	46	
3	FT18W/2G11	1.5	MAG EE	Magnetic Energy Efficient	69	Tandem wired
3	FT18W/2G11	2	MAG EE	Magnetic Energy Efficient	69	
4	FT18W/2G11	2	MAG EE	Magnetic Energy Efficient	92	(2) Two-lamp ballasts
1	FT18W/2G11	1	ELECT	Electronic	17	
2	FT18W/2G11	1	ELECT	Electronic	35	
3	FT18W/2G11	1.5	ELECT	Electronic	52	Tandem wired
3	FT18W/2G11	2	ELECT	Electronic	52	
4	FT18W/2G11	2	ELECT	Electronic	70	(2) Two-lamp ballasts
Fluorescent Twin (24-27W- F24TT or F27TT Lamp)						
1	FT24W/2G11	1	MAG EE	Magnetic Energy Efficient	32	
2	FT24W/2G11	1	MAG EE	Magnetic Energy Efficient	66	
3	FT24W/2G11	1.5	MAG EE	Magnetic Energy Efficient	99	Tandem wired
3	FT24W/2G11	2	MAG EE	Magnetic Energy Efficient	98	
4	FT24W/2G11	2	MAG EE	Magnetic Energy Efficient	132	(2) Two-lamp ballasts
1	FT24W/2G11	1	ELECT	Electronic	21	
2	FT24W/2G11	1	ELECT	Electronic	43	
3	FT24W/2G11	1.5	ELECT	Electronic	64	Tandem wired
3	FT24W/2G11	2	ELECT	Electronic	64	
4	FT24W/2G11	2	ELECT	Electronic	86	(2) Two-lamp ballasts
Fluorescent Twin (36-39W - F36TT or F39TT Lamp)						
1	FT36W/2G11	1	MAG EE	Magnetic Energy Efficient	51	
2	FT36W/2G11	1	MAG EE	Magnetic Energy Efficient	66	
3	FT36W/2G11	1.5	MAG EE	Magnetic Energy Efficient	99	Tandem wired
3	FT36W/2G11	2	MAG EE	Magnetic Energy Efficient	117	
4	FT36W/2G11	2	MAG EE	Magnetic Energy Efficient	132	(2) Two-lamp ballasts
1	FT36W/2G11	1	ELECT	Electronic	37	
2	FT36W/2G11	1	ELECT	Electronic	70	
3	FT36W/2G11	1.5	ELECT	Electronic	105	Tandem wired
3	FT36W/2G11	2	ELECT	Electronic	107	
4	FT36W/2G11	2	ELECT	Electronic	140	(2) Two-lamp ballasts

LUMINAIRE LUMIN.

Lamp No.	Lamp Designation	Ballast No.	Ballast Abbreviation	Ballast Description	Watts/ Luminaire	Comments
Fluorescent Twin (40 W - F40TT Lamp)						
1	FT40W/2G11	1	MAG EE	Magnetic Energy Efficient	43	
2	FT40W/2G11	1	MAG EE	Magnetic Energy Efficient	86	
3	FT40W/2G11	1.5	MAG EE	Magnetic Energy Efficient	129	Tandem wired
3	FT40W/2G11	2	MAG EE	Magnetic Energy Efficient	130	
4	FT40W/2G11	2	MAG EE	Magnetic Energy Efficient	172	(2) Two-lamp ballasts
1	FT40W/2G11	1	ELECT	Electronic	36	
2	FT40W/2G11	1	ELECT	Electronic	71	
2	FT40W/2G11	1	ELECT	Electronic	70	
3	FT40W/2G11	1	ELECT	Electronic	98	
3	FT40W/2G11	1.5	ELECT	Electronic	106	Tandem wired
3	FT40W/2G11	2	ELECT	Electronic	107	
4	FT40W/2G11	2	ELECT	Electronic	142	(2) Two-lamp ballasts
2	FT40W/2G11	1	ELECT RO	Elec. Reduce Output (75%)	59	
3	FT40W/2G11	1.5	ELECT DIM	Electronic Dimming (to 1%)	105	Tandem wired
4	FT40W/2G11	2	ELECT DIM	Electronic Dimming (to 1%)	140	(2) two-lamp ballasts
Fluorescent Twin (50 W - F50TT Lamp)						
1	FT50W/2G11	1	ELECT	Electronic	54	
2	FT50W/2G11	1	ELECT	Electronic	106	
3	FT50W/2G11	1	ELECT	Electronic	98	
3	FT50W/2G11	1.5	ELECT	Electronic	159	Tandem wired
3	FT50W/2G11	2	ELECT	Electronic	160	
4	FT50W/2G11	2	ELECT	Electronic	212	(2) Two-lamp ballasts
Fluorescent Twin (55 W - F55TT Lamp)						
1	FT55W/2G11	1	ELECT	Electronic	62	
2 ft. Fluorescent U-Tube Octic (32W - FBO31T8 Lamp)						
1	FB31T8	0.5	MAG EE	Magnetic Energy Efficient	35	Tandem wired
1	FB31T8	1	MAG EE	Magnetic Energy Efficient	36	
2	FB31T8	1	MAG EE	Magnetic Energy Efficient	69	
3	FB31T8	1.5	MAG EE	Magnetic Energy Efficient	104	Tandem wired
3	FB31T8	2	MAG EE	Magnetic Energy Efficient	105	

LUMINAIRE POWER

Lamp		Ballast			Watts/	
No.	Designation	No.	Abbreviation	Description	Luminaire	Comments
1	FB31T8	0.5	ELECT	Electronic	31	Tandem wired
1	FB31T8	1	ELECT	Electronic	39	
2	FB31T8	1	ELECT	Electronic	62	
3	FB31T8	1	ELECT	Electronic	92	
3	FB31T8	1.5	ELECT	Electronic	93	Tandem wired
3	FB31T8	2	ELECT	Electronic	101	
2	FB31T8	1	ELECT IS	Electronic Instant Start	61	
3	FB31T8	1	ELECT IS	Electronic Instant Start	88	
2 ft. Fluorescent U-Tube Energy-Saving (34W)						
1	FB40T12/ES	0.5	MAG EE	Magnetic Energy Efficient	36	Tandem wired
1	FB40T12/ES	1	MAG EE	Magnetic Energy Efficient	43	
2	FB40T12/ES	1	MAG EE	Magnetic Energy Efficient	72	
3	FB40T12/ES	1	MAG EE	Magnetic Energy Efficient	105	
3	FB40T12/ES	1.5	MAG EE	Magnetic Energy Efficient	108	Tandem wired
3	FB40T12/ES	2	MAG EE	Magnetic Energy Efficient	115	
1	FB40T12/ES	0.5	ELECT	Electronic	30	Tandem wired
1	FB40T12/ES	1	ELECT	Electronic	31	
2	FB40T12/ES	1	ELECT	Electronic	59	
3	FB40T12/ES	1	ELECT	Electronic	90	
3	FB40T12/ES	1.5	ELECT	Electronic	88	Tandem wired
3	FB40T12/ES	2	ELECT	Electronic	90	
2 ft. Fluorescent U-Tube Standard (40W - FB40T12 Lamp)						
1	FB40T12	0.5	MAG EE	Magnetic Energy Efficient	43	Tandem wired
1	FB40T12	1	MAG EE	Magnetic Energy Efficient	48	
2	FB40T12	1	MAG EE	Magnetic Energy Efficient	86	
3	FB40T12	1	MAG EE	Magnetic Energy Efficient	127	
3	FB40T12	1.5	MAG EE	Magnetic Energy Efficient	129	Tandem wired
3	FB40T12	2	MAG EE	Magnetic Energy Efficient	134	
1	FB40T12	0.5	ELECT	Electronic	35	Tandem wired
1	FB40T12	1	ELECT	Electronic	36	
2	FB40T12	1	ELECT	Electronic	67	
3	FB40T12	1	ELECT	Electronic	100	
3	FB40T12	1.5	ELECT	Electronic	101	Tandem wired
3	FB40T12	2	ELECT	Electronic	103	

Table B-11–Luminaire Power (continued)

LUMINAIRE POWER

Lamp		Ballast			Watts/	
No.	Designation	No.	Abbreviation	Description	Luminaire	Comments
Fluorescent Preheat T5 (4W)						
1	F4T5	1	MAG STD	Magnetic Standard	8	6" MOL
Fluorescent Preheat T5 (6W)						
1	F6T5	1	MAG STD	Magnetic Standard	10	9" MOL
Fluorescent Preheat T5 (8W)						
1	F8T5	1	MAG STD	Magnetic Standard	12	12" MOL
Fluorescent Preheat T8 (15W)						
1	F15T8	1	MAG STD	Magnetic Standard	19	18" MOL
Fluorescent Preheat T12 (15W)						
1	F15T12	1	MAG STD	Magnetic Standard	19	18" MOL
Fluorescent Preheat T12 (20W)						
1	F20T12	1	MAG STD	Magnetic Standard	25	24" MOL
2	F20T12	1	MAG STD	Magnetic Standard	50	24" MOL
Fluorescent Preheat T8 (30W)						
1	F30T8	1	MAG STD	Magnetic Standard	46	30" MOL
2	F30T8	1	MAG STD	Magnetic Standard	79	30" MOL
Fluorescent Preheat T12 (30W)						
1	F30T12	1	MAG STD	Magnetic Standard	46	30" MOL
2	F30T12	1	MAG STD	Magnetic Standard	79	30" MOL
2	F30T12	1	MAG EE	Magnetic Energy Efficient	74	30" MOL
1	F30T12	1	ELECT	Electronic	31	30" MOL
2	F30T12	2	ELECT	Electronic	63	30" MOL
2 foot Fluorescent Rapid Start T8 (17W)						
1	F17T8	1	MAG EE	Magnetic Energy Efficient	24	
2	F17T8	1	MAG EE	Magnetic Energy Efficient	45	
1	F17T8	1	ELECT	Electronic	22	
2	F17T8	1	ELECT	Electronic	33	
3	F17T8	1	ELECT	Electronic	53	
3	F17T8	2	ELECT	Electronic	55	
4	F17T8	1	ELECT	Electronic	63	
4	F17T8	2	ELECT	Electronic	66	(2) two-lamp ballasts

Table B-11–Luminaire Power (continued)

LUMINAIRE POWER

Lamp		Ballast			Watts/ Luminaire	Comments
No.	Designation	No.	Abbreviation	Description		
3 foot Fluorescent Rapid Start T8 (25W)						
1	F25T8	1	MAG EE	Magnetic Energy Efficient	33	
2	F25T8	1	MAG EE	Magnetic Energy Efficient	65	
1	F25T8	1	ELECT	Electronic	27	
2	F25T8	1	ELECT	Electronic	48	
3	F25T8	1	ELECT	Electronic	68	
3	F25T8	2	ELECT	Electronic	75	
4	F25T8	1	ELECT	Electronic	89	
4	F25T8	2	ELECT	Electronic	96	(2) two-lamp ballasts
4 foot Fluorescent Rapid Start Octic (32W)						
1	F32T8	0.5	MAG EE	Magnetic Energy Efficient	35	Tandem wired
1	F32T8	1	MAG EE	Magnetic Energy Efficient	39	
2	F32T8	1	MAG EE	Magnetic Energy Efficient	70	
3	F32T8	1.5	MAG EE	Magnetic Energy Efficient	105	Tandem wired
3	F32T8	2	MAG EE	Magnetic Energy Efficient	109	
4	F32T8	2	MAG EE	Magnetic Energy Efficient	140	(2) two-lamp ballasts
1	F32T8	0.5	ELECT	Electronic	31	Tandem wired
1	F32T8	1	ELECT	Electronic	32	
2	F32T8	1	ELECT	Electronic	62	
3	F32T8	1	ELECT	Electronic	93	
3	F32T8	1.5	ELECT	Electronic	93	Tandem wired
3	F32T8	2	ELECT	Electronic	94	
4	F32T8	1	ELECT	Electronic	114	
4	F32T8	2	ELECT	Electronic	124	(2) two-lamp ballasts
2	F32T8	1	ELECT IS	Electronic Instant Start	63	
3	F32T8	1	ELECT IS	Electronic Instant Start	96	
3	F32T8	1.5	ELECT IS	Electronic Instant Start	95	Tandem wired
4	F32T8	1	ELECT IS	Electronic Instant Start	124	
4	F32T8	2	ELECT IS	Electronic Instant Start	126	(2) two-lamp ballasts

LUMINAIRE POWER

Lamp No.	Lamp Designation	Ballast No.	Ballast Abbreviation	Ballast Description	Watts/ Luminaire	Comments
4 foot Fluorescent Rapid Start Octic (32W) (cont.)						
2	F32T8	1	ELECT RO	Electronic Reduce Output (75%)	51	
3	F32T8	1	ELECT RO	Electronic Reduce Output (75%)	76	
3	F32T8	1.5	ELECT RO	Electronic Reduce Output (75%)	77	Tandem wired
4	F32T8	1	ELECT RO	Electronic Reduce Output (75%)	100	
4	F32T8	2	ELECT RO	Electronic Reduce Output (75%)	102	(2) two-lamp ballasts
2	F32T8	1	ELECT TL	Electronic Two Level (50 & 100%)	65	
3	F32T8	1.5	ELECT TL	Electronic Two Level (50 & 100%)	98	Tandem wired
4	F32T8	2	ELECT TL	Electronic Two Level (50 & 100%)	130	(2) two-lamp ballasts
2	F32T8	1	ELECT AO	Electronic Adjustable Output (to 15%)	73	
3	F32T8	1.5	ELECT AO	Electronic Adjustable Output (to 15%)	110	Tandem wired
4	F32T8	2	ELECT AO	Electronic Adjustable Output (to 15%)	146	(2) two-lamp ballasts
2	F32T8	1	ELECT DIM	Electronic Dimming (to 1%)	75	
3	F32T8	1.5	ELECT DIM	Electronic Dimming (to 1%)	113	Tandem wired
4	F32T8	2	ELECT DIM	Electronic Dimming (to 1%)	150	(2) two-lamp ballasts
5 foot Fluorescent Rapid Start (40W)						
1	F40T8	1	MAG EE	Magnetic Energy Efficient	50	
2	F40T8	1	MAG EE	Magnetic Energy Efficient	92	
1	F40T8	1	ELECT	Electronic	46	
2	F40T8	1	ELECT	Electronic	79	
3	F40T8	2	ELECT	Electronic	109	
3 foot Fluorescent Rapid Start Energy-Saving (25W)						
1	F30T12/ES	1	MAG STD	Magnetic Standard	42	
2	F30T12/ES	1	MAG STD	Magnetic Standard	74	
3	F30T12/ES	1.5	MAG STD	Magnetic Standard	111	Tandem wired
3	F30T12/ES	2	MAG STD	Magnetic Standard	116	
2	F30T12/ES	1	MAG EE	Magnetic Energy Efficient	66	
1	F30T12/ES	1	ELECT	Electronic	26	
2	F30T12/ES	1	ELECT	Electronic	53	

LUMINAIRE POWER

Lamp No.	Lamp Designation	Ballast No.	Ballast Abbreviation	Ballast Description	Watts/ Luminaire	Comments
3 foot Fluorescent Rapid Start Standard (30W)						
1	F30T12	1	MAG STD	Magnetic Standard	46	
2	F30T12	1	MAG STD	Magnetic Standard	79	
3	F30T12	1.5	MAG STD	Magnetic Standard	118	Tandem wired
3	F30T12	2	MAG STD	Magnetic Standard	125	
4 foot Fluorescent Rapid Start Energy-Saving Plus (32W)						
1	F40T12/ES Plus	0.5	MAG EE	Magnetic Energy Efficient	34	Tandem wired
1	F40T12/ES Plus	1	MAG EE	Magnetic Energy Efficient	41	
2	F40T12/ES Plus	1	MAG EE	Magnetic Energy Efficient	68	
3	F40T12/ES Plus	1	MAG EE	Magnetic Energy Efficient	99	
3	F40T12/ES Plus	1.5	MAG EE	Magnetic Energy Efficient	102	Tandem wired
3	F40T12/ES Plus	2	MAG EE	Magnetic Energy Efficient	109	
4	F40T12/ES Plus	2	MAG EE	Magnetic Energy Efficient	136	(2) Two-lamp ballasts
4 foot Fluorescent Rapid Start Energy-Saving (34W)						
1	F40T12/ES	0.5	MAG STD**	Magnetic Standard	42	Tandem wired
1	F40T12/ES	1	MAG STD**	Magnetic Standard	48	
2	F40T12/ES	1	MAG STD**	Magnetic Standard	82	
3	F40T12/ES	1.5	MAG STD**	Magnetic Standard	122	Tandem wired
3	F40T12/ES	2	MAG STD**	Magnetic Standard	130	
4	F40T12/ES	2	MAG STD**	Magnetic Standard	164	(2) Two-lamp ballasts
1	F40T12/ES	0.5	MAG EE	Magnetic Energy Efficient	36	Tandem wired
1	F40T12/ES	1	MAG EE	Magnetic Energy Efficient	43	
2	F40T12/ES	1	MAG EE	Magnetic Energy Efficient	72	
3	F40T12/ES	1	MAG EE	Magnetic Energy Efficient	105	
3	F40T12/ES	1.5	MAG EE	Magnetic Energy Efficient	108	Tandem wired
3	F40T12/ES	2	MAG EE	Magnetic Energy Efficient	112	
4	F40T12/ES	2	MAG EE	Magnetic Energy Efficient	144	(2) Two-lamp ballasts
2	F40T12/ES	1	MAG HC	Magnetic Heater Cutout	58	
3	F40T12/ES	1.5	MAG HC	Magnetic Heater Cutout	87	Tandem wired
4	F40T12/ES	2	MAG HC	Magnetic Heater Cutout	116	(2) Two-lamp ballasts
2	F40T12/ES	1	MAG HC FO	Mag. Heater Cutout Full Light	66	
3	F40T12/ES	1.5	MAG HC FO	Mag. Heater Cutout Full Light	99	Tandem wired
4	F40T12/ES	2	MAG HC FO	Mag. Heater Cutout Full Light	132	(2) Two-lamp ballasts

Table B-11–Luminaire Power (continued)

LUMINAIRE POWER

Lamp		Ballast			Watts/	
No.	Designation	No.	Abbreviation	Description	Luminaire	Comments
4 foot Fluorescent Rapid Start Energy-Saving (34W) (cont.)						
1	F40T12/ES	0.5	ELECT	Electronic	30	Tandem wired
1	F40T12/ES	1	ELECT	Electronic	31	
2	F40T12/ES	1	ELECT	Electronic	62	
3	F40T12/ES	1	ELECT	Electronic	90	
3	F40T12/ES	1.5	ELECT	Electronic	93	Tandem wired
3	F40T12/ES	2	ELECT	Electronic	93	
4	F40T12/ES	1	ELECT	Electronic	121	
4	F40T12/ES	2	ELECT	Electronic	124	(2) Two-lamp ballasts
2	F40T12/ES	1	ELECT AO	Elec. Adjustable Output (to 15%)	60	
3	F40T12/ES	1.5	ELECT AO	Elec. Adjustable Output (to 15%)	90	Tandem wired
4	F40T12/ES	2	ELECT AO	Elec. Adjustable Output (to 15%)	120	(2) Two-lamp ballasts
4 foot Fluorescent Rapid Start Standard (40W)						
1	F40T12	0.5	MAG STD**	Magnetic Standard	26	Tandem wired
1	F40T12	1	MAG STD**	Magnetic Standard	52	
2	F40T12	1	MAG STD**	Magnetic Standard	96	
3	F40T12	1.5	MAG STD**	Magnetic Standard	144	Tandem wired
3	F40T12	2	MAG STD**	Magnetic Standard	148	
4	F40T12	2	MAG STD**	Magnetic Standard	192	(2) Two-lamp ballasts
1	F40T12	0.5	MAG EE	Magnetic Energy Efficient	44	Tandem wired
1	F40T12	1	MAG EE	Magnetic Energy Efficient	46	
2	F40T12	1	MAG EE	Magnetic Energy Efficient	88	
3	F40T12	1	MAG EE	Magnetic Energy Efficient	127	
3	F40T12	1.5	MAG EE	Magnetic Energy Efficient	132	Tandem wired
3	F40T12	2	MAG EE	Magnetic Energy Efficient	134	
4	F40T12	2	MAG EE	Magnetic Energy Efficient	176	(2) Two-lamp ballasts
2	F40T12	1	MAG HC	Magnetic Heater Cutout	71	
3	F40T12	1.5	MAG HC	Magnetic Heater Cutout	107	Tandem wired
4	F40T12	2	MAG HC	Magnetic Heater Cutout	142	(2) Two-lamp ballasts

LUMINAIRE POWER

Lamp No.	Lamp Designation	Ballast No.	Ballast Abbreviation	Ballast Description	Watts/ Luminaire	Comments
4 foot Fluorescent Rapid Start Standard (40W) (cont.)						
2	F40T12	1	MAG HC FO	Magnetic Heater Cutout Full Light	80	
3	F40T12	1.5	MAG HC FO	Magnetic Heater Cutout Full Light	120	Tandem wired
4	F40T12	2	MAG HC FO	Magnetic Heater Cutout Full Light	160	(2) Two-lamp ballasts
1	F40T12	0.5	ELECT	Electronic	36	Tandem wired
1	F40T12	1	ELECT	Electronic	37	
2	F40T12	1	ELECT	Electronic	72	
3	F40T12	1	ELECT	Electronic	107	
3	F40T12	1.5	ELECT	Electronic	108	Tandem wired
3	F40T12	2	ELECT	Electronic	109	
4	F40T12	1	ELECT	Electronic	135	
4	F40T12	2	ELECT	Electronic	144	(2) Two-lamp ballasts
2	F40T12	1	ELECT RO	Electronic Reduce Output (75%)	61	
3	F40T12	1	ELECT RO	Electronic Reduce Output (75%)	90	
3	F40T12	1.5	ELECT RO	Electronic Reduce Output (75%)	92	Tandem wired
4	F40T12	2	ELECT RO	Electronic Reduce Output (75%)	122	(2) Two-lamp ballasts
2	F40T12	1	ELECT TL	Elec. Two Level (50 & 100%)	69	
3	F40T12	1.5	ELECT TL	Elec. Two Level (50 & 100%)	104	Tandem wired
4	F40T12	2	ELECT TL	Elec. Two Level (50 & 100%)	138	(2) Two-lamp ballasts
2	F40T12	1	ELECT AO	Elec. Adjustable Output (to 15%)	73	
3	F40T12	1.5	ELECT AO	Elec. Adjustable Output (to 15%)	110	Tandem wired
4	F40T12	2	ELECT AO	Elec. Adjustable Output (to 15%)	146	(2) Two-lamp ballasts
2	F40T12	1	ELECT DIM	Electronic Dimming (to 1%)	83	
3	F40T12	1.5	ELECT DIM	Electronic Dimming (to 1%)	125	Tandem wired
4	F40T12	2	ELECT DIM	Electronic Dimming (to 1%)	166	(2) Two-lamp ballasts

LUMINAIRE POWER

Lamp		Ballast			Watts/	
No.	Designation	No.	Abbreviation	Description	Luminaire	Comments
4 foot Fluorescent Rapid Start Extended Output (42W)						
2	F40T10/EO	1	MAG EE	Magnetic Energy Efficient	92	
3	F40T10/EO	1.5	MAG EE	Magnetic Energy Efficient	138	Tandem wired
4	F40T10/EO	2	MAG EE	Magnetic Energy Efficient	184	(2) Two-lamp ballasts
2	F40T10/EO	1	MAG HC	Magnetic Heater Cutout	74	
3	F40T10/EO	1.5	MAG HC	Magnetic Heater Cutout	111	Tandem wired
4	F40T10/EO	2	MAG HC	Magnetic Heater Cutout	148	(2) Two-lamp ballasts
2	F40T10/EO	1	ELECT	Electronic	74	
3	F40T10/EO	1.5	ELECT	Electronic	111	Tandem wired
4	F40T10/EO	2	ELECT	Electronic	148	(2) Two-lamp ballasts
2	F40T10/EO	1	ELECT RO	Electronic Reduce Output (75%)	63	
3	F40T10/EO	1.5	ELECT RO	Electronic Reduce Output (75%)	95	Tandem wired
4	F40T10/EO	2	ELECT RO	Electronic Reduce Output (75%)	126	(2) Two-lamp ballasts
2	F40T10/EO	1	ELECT TL	Elec. Two Level (50 & 100%)	72	
3	F40T10/EO	1.5	ELECT TL	Elec. Two Level (50 & 100%)	108	Tandem wired
4	F40T10/EO	2	ELECT TL	Elec. Two Level (50 & 100%)	144	(2) Two-lamp ballasts
2	F40T10/EO	1	ELECT AO	Elec. Adjustable Output (to 15%)	73	
3	F40T10/EO	1.5	ELECT AO	Elec. Adjustable Output (to 15%)	110	Tandem wired
4	F40T10/EO	2	ELECT AO	Elec. Adjustable Output (to 15%)	146	(2) Two-lamp ballasts
2	F40T10/EO	1	ELECT DIM	Electronic Dimming (to 1%)	85	
3	F40T10/EO	1.5	ELECT DIM	Electronic Dimming (to 1%)	128	Tandem wired
4	F40T10/EO	2	ELECT DIM	Electronic Dimming (to 1%)	170	(2) Two-lamp ballasts

Table B-11–Luminaire Power (continued)

LUMINAIRE POWER

Lamp		Ballast			Watts/	
No.	Designation	No.	Abbreviation	Description	Luminaire	Comments
8 foot Fluorescent Rapid Start High Output Energy-Saving (86W)						
2	F96T8/HO	1	ELECT	Electronic	160	
8 foot Fluorescent Rapid Start High Output Energy-Saving (95W)						
1	F96T12/HO/ES	1	MAG STD	Magnetic Standard	125	
2	F96T12/HO/ES	1	MAG STD**	Magnetic Standard	227	
2	F96T12/HO/ES	1	MAG EE	Magnetic Energy Efficient	208	
4	F96T12/HO/ES	2	MAG EE	Magnetic Energy Efficient	416	(2) Two-lamp ballasts
2	F96T12/HO/ES	1	ELECT	Electronic	160	
4	F96T12/HO/ES	2	ELECT	Electronic	320	(2) Two-lamp ballasts
8 foot Fluorescent Rapid Start High Output (110W)						
1	F96T12/HO	1	MAG STD	Magnetic Standard	140	
2	F96T12/HO	1	MAG STD**	Magnetic Standard	252	
2	F96T12/HO	1	MAG EE	Magnetic Energy Efficient	237	
4	F96T12/HO	2	MAG EE	Magnetic Energy Efficient	474	(2) Two-lamp ballasts
2	F96T12/HO	1	ELECT	Electronic	190	
4	F96T12/HO	2	ELECT	Electronic	380	(2) Two-lamp ballasts
8 foot Fluorescent Rapid Start Very High Output Energy-Saving (195W)						
1	F96T12/VHO/ES	1	MAG STD	Magnetic Standard	200	
2	F96T12/VHO/ES	1	MAG STD	Magnetic Standard	325	
4	F96T12/VHO/ES	2	MAG STD	Magnetic Standard	650	(2) Two-lamp ballasts
8 foot Fluorescent Rapid Start Very High Output (215W)						
1	F96T12/VHO	1	MAG STD	Magnetic Standard	230	
2	F96T12/VHO	1	MAG STD	Magnetic Standard	440	
4	F96T12/VHO	2	MAG STD	Magnetic Standard	880	

LUMINAIRE POWER

Lamp No.	Lamp Designation	Ballast No.	Ballast Abbreviation	Ballast Description	Watts/ Luminaire	Comments
4 foot Fluorescent Slimline Energy-Saving T12 (32W)						
1	F48T12/ES	1	MAG STD	Magnetic Standard	51	
2	F48T12/ES	1	MAG STD	Magnetic Standard	82	
4 foot Fluorescent Slimline Standard T12 (39W)						
1	F48T12	1	MAG STD	Magnetic Standard	59	
2	F48T12	1	MAG STD	Magnetic Standard	98	
8 foot Fluorescent Instant Start T8 (Slimline with Rare Earth Phosphors)						
1	F96T8	1	ELECT	Electronic	71	
2	F96T8	1	ELECT	Electronic	115	
8 foot Fluorescent Slimline Energy-Saving (60W)						
1	F96T12/ES	1	MAG STD	Magnetic Standard	83	
2	F96T12/ES	1	MAG STD**	Magnetic Standard	138	
2	F96T12/ES	1	MAG EE	Magnetic Energy Efficient	123	
4	F96T12/ES	2	MAG EE	Magnetic Energy Efficient	246	(2) Two-lamp ballasts
2	F96T12/ES	1	ELECT	Electronic	105	
4	F96T12/ES	2	ELECT	Electronic	210	(2) Two-lamp ballasts
8 foot Fluorescent Slimline Standard (75W)						
1	F96T12	1	MAG STD	Magnetic Standard	100	
2	F96T12	1	MAG STD**	Magnetic Standard	173	
2	F96T12	1	MAG EE	Magnetic Energy Efficient	158	
4	F96T12	2	MAG EE	Magnetic Energy Efficient	316	(2) Two-lamp ballasts
2	F96T12	1	ELECT	Electronic	130	
4	F96T12	2	ELECT	Electronic	260	(2) Two-lamp ballasts
2	F96T12	1	ELECT IS	Electronic Instant Start	130	
3	F96T12	1.5	ELECT IS	Electronic Instant Start	195	Tandem wired
4	F96T12	2	ELECT IS	Electronic Instant Start	260	(2) Two-lamp ballasts

LUMINAIRE POWER

Lamp		Ballast			Watts/	
No.	Designation	No.	Abbreviation	Description	Luminaire	Comments
Mercury Vapor						
1	MV40	1	MAG STD	Magnetic Standard	51	
1	MV50	1	MAG STD	Magnetic Standard	63	
1	MV75	1	MAG STD	Magnetic Standard	88	
1	MV100	1	MAG STD	Magnetic Standard	119	
1	MV175	1	MAG STD	Magnetic Standard	197	
1	MV250	1	MAG STD	Magnetic Standard	285	
1	MV400	1	MAG STD	Magnetic Standard	450	
1	MV1000	1	MAG STD	Magnetic Standard	1080	
Metal Halide						
1	MH32	1	MAG STD	Magnetic Standard	42	
1	MH70	1	MAG STD	Magnetic Standard	95	
1	MH100	1	MAG STD	Magnetic Standard	142	
1	MH175	1	MAG STD	Magnetic Standard	210	
1	MH250	1	MAG STD	Magnetic Standard	295	
1	MH400	1	MAG STD	Magnetic Standard	461	
1	MH1000	1	MAG STD	Magnetic Standard	1080	
High Pressure Sodium						
1	HPS35	1	MAG STD	Magnetic Standard	44	
1	HPS50	1	MAG STD	Magnetic Standard	61	
1	HPS70	1	MAG STD	Magnetic Standard	93	
1	HPS100	1	MAG STD	Magnetic Standard	116	
1	HPS150	1	MAG STD	Magnetic Standard	173	
1	HPS200	1	MAG STD	Magnetic Standard	240	
1	HPS250	1	MAG STD	Magnetic Standard	302	
1	HPS400	1	MAG STD	Magnetic Standard	469	
1	HPS1000	1	MAG STD	Magnetic Standard	1090	
Low Pressure Sodium						
1	LPS18	1	MAG STD	Magnetic Standard	30	
1	LPS35	1	MAG STD	Magnetic Standard	60	
1	LPS55	1	MAG STD	Magnetic Standard	80	
1	LPS90	1	MAG STD	Magnetic Standard	125	
1	LPS135	1	MAG STD	Magnetic Standard	178	
1	LPS180	1	MAG STD	Magnetic Standard	220	

LUMINAIRE POWER

Lamp No.	Lamp Designation	Ballast No.	Ballast Abbreviation	Ballast Description	Watts/ Luminaire	Comments
12 Volt Tungsten Halogen, MR 16 & Electronic Transformer						
1	Q20MR16(12V)	1	ELECT	Electronic	23	
1	Q35MR16(12V)	1	ELECT	Electronic	39	
1	Q50MR16(12V)	1	ELECT	Electronic	55	
1	Q70MR16(12V)	1	ELECT	Electronic	78	

*** US Energy Policy Act of 1992 affect on lamps**
Beginning in April 1994, many common wattage lamp types can no longer be manufactured or imported into the U.S. Federal Energy Legislation has decreed that these lamp types must be eliminated to reduce energy consumption. Lamp Types affected include the following fluorescent lamps:

Fluorescent Lamps	F40U/3 Cool White	F96T12/	W
F40 CW	F40U/3 Warm White	F96T12/	WW
F40 D	F40U/6 Cool White	F96T12/	WWX
F40 D/WM	F40U/6 Warm White Deluxe	F96T12/	WWX/WM
F40 W	F40U/6 Warm White	F96T12/	HO/D
F40 WW	F96T12/ CW	F96T12/	HO/CW
F40 WWX	F96T12/ D	F96T12/	HO/W
F40 WWX/WM	F96T12/ D/WM	F96T12/	HO/WW

Incandescent PAR Lamps		Inc. Reflector Lamps	
75PAR38	150PAR38	75R40	200R40
75/65PAR38	150/120PAR38	75R30	
100/80PAR38		150R40	
100 PAR38		100R40	

**** US National Appliance Energy Conservation Act of 1988 affect on ballasts**
In 1991 using the following Standard Magnetic ballasts was not permitted in the US.

-Single and two-lamp ballasts for 4' T12 Rapid Start Lamps, 120V & 277V 60Hz
-Two-lamp ballasts for 8' T-12 Slimline lamps
-Two-lamp ballasts for 8' T12 high-output rapid start lamps

ALTERNATIVE CALCULATION METHOD
For Nonresidential Buildings-
Solar Heat Gain Coefficient Compliance

APPLICABLE STANDARD: Energy Efficiency Standards for Nonresidential Buildings

AUDIENCE: Building Officials, Architects, Engineers, Designers and Energy Documentation Consultants
EFFECTIVE DATE: July 1, 1999
AVAILABILITY: July 1, 1999
LEVEL OF CHANGE: Optional

Summary:
The California Energy Commission approved a new Alternative Calculation Method (ACM) for energy consultants, designers, architects, and builders to demonstrate compliance with Solar Heat Gain Coefficient (SHGC) values required by the Efficiency Standards for Nonresidential Buildings. This method specifically applies to fenestration products, including glass and frame, that do not have SHGC values published by the National Fenestration Rating Council (NFRC) in their Certified Products Directory. For information on other shading alternatives and how to apply the results of this calculation method, see the *1998 Nonresidential Manual*.
Recently the Energy Commission updated the regulations for 1998 nonresidential buildings to express the shading requirements for fenestration products in terms of SHGC of the entire product, including frame. This update only allowed use of the default SHGC for products without certified SHGC values. The SHGC values in the Energy Commission's default table are intended to be conservative and do not represent the types of products typically used in a large portion of nonresidential construction. The majority of products typically used also do not have SHGC values published by NFRC and cannot be used with the 1998 standards unless the Commission provides an alternative calculation method for determining compliance.
This alternative calculation methodology expands available shading alternatives by providing a method to use the SHGC for the glass alone, which can be used to determine compliance for manufactured, site-assembled, and field-fabricated fenestration products. Instructions are separately provided below for Prescriptive or Performance compliance approaches along with a description of responsibilities for energy consultants/designers/architects, builders, installers, and building department plan and field inspectors.

Compliance Using the Prescriptive and Performance Approach

Site-Assembled Fenestration Products and Field-fabricated Fenestration
This section describes the alternative calculation method for determining compliance for site-assembled and field-fabricated products.
Site-assembled fenestration includes both field-fabricated fenestration and fenestration whose frame is previously cut or formed by a manufacturer with the specific intention of being used with a glass assembly to create a complete fenestration product. Field-fabricated fenestration is a fenestration product whose frame is made at the construction site of standard dimensional lumber or other materials that were not previously cut, or otherwise formed with the specific intention of being used to fabricate a fenestration product.
Use the following equation to calculate the shading value for fenestration that is used to determine compliance. Convert the center of glass shading value, $SHGC_c$, from the manufacturer's documentation to a shading value for the fenestration product including framing,

$SHGC_{fen,}$
$$\mathbf{SHGC_{fen} = 0.08 + 0.86 \times SHGC_c}$$
Where:

$SHGC_c$ is the SHGC for the center of glass alone, and $SHGC_{fen}$ is the SHGC for the fenestration including glass and frame.

Manufactured Fenestration Products

This section describes the alternative calculation method for determining compliance for manufactured products that do not have SHGC values published by the National Fenestration Rating Council (NFRC) in their Certified Products Directory.

Manufactured Fenestration Products without a SHGC certified to National Fenestration Rating Council, NFRC, are similar to those that have a SHGC certified to NFRC. They are complete products, shipped from the manufacturer with the frame and glazing already assembled. These products may be listed in the *NFRC Certified Products Directory* with their U-factor, but not with a SHGC. To determine compliance with the building efficiency standards the center of glass SHGC from the manufacturer's documentation for the proposed glazing must be converted to an SHGC for the fenestration that includes the framing effect.

Use the following equation to calculate the shading value for fenestration that is used to determine compliance. Convert the center of glass shading value, $SHGC_c$ from the manufacturer's documentation to a shading value for the fenestration product including framing, $SHGC_{fen}$,

$SHGC_{fen} = 0.11 + 0.81 \times SHGC_c$

Where:

$SHGC_c$ is the SHGC for the center of glass alone, and

$SHGC_{fen}$ is the SHGC for the fenestration including glass and frame.

Solar Heat Gain Coefficient (SHGC)

Responsibilities for Compliance

This section describes the responsibilities of energy consultants, designers, architects, builders, installers, and building departments when determining compliance with SHGC requirements.

Energy Consultants, Designers, Architects

Products with SHGCs Certified to NFRC

SHGCs can be found in the NFRC *Certified Products Directory,* SV section. Contact NFRC at 301-589-6372 for a copy of the directory or go to NFRC's website at www.nfrc.org for an online database of the directory.

Field-Fabricated Fenestration, Site-Assembled Fenestration and Fenestration Products without SHGC Certified to NFRC

The procedure described below does not apply to site-assembled vertical glazing in buildings with (a) 100,000 sf or more of conditioned floor area and (b) 10,000 sf or more of vertical fenestration area. For these glazing assemblies, use the NFRC 100SB Label Certificate procedure described above. (For projects where the building has 100,000 sf or more of conditioned space and 10,000 sf or more of vertical fenestration area, the SHGC of the vertical glazing must be obtained using NFRC 100SB and must be verified by a Label Certificate for Site-Built Products. The Label Certificate must be included with the plans or be provided on site at the time of inspection.)

To determine compliance with the efficiency standards, the center of glass SHGC from the manufacturer's documentation for the proposed glazing must be converted to an $SHGC_{fen}$ for the fenestration that includes the framing effect. For the Prescriptive compliance method, the $SHGC_{fen}$ is then entered into the prescriptive ENV-1 form, Part 2 of 2 and must appear on the plans.

For the Performance compliance method, the $SHGC_{fen}$ output information printed on the Performance ENV-1 form must be listed on the building plans. The PERF-1 and Performance

ENV-1 forms must appear on the plans. The building plan window schedule list must indicate the proposed total $SHGC_{fen}$ values for each fenestration assembly, and these values must be equal to the SHGCs listed on the Performance ENV-1 computer form. (Note: an under-calculation of space conditioning energy can result from entering either too low or too high an $SHGC_{fen}$ for the product.) The proposed design $SHGC_{fen}$ values are entered into the computer program to automatically generate the energy budget of the standard design and the energy use of the proposed design. The building complies if the total energy use of the proposed design is the same or less than the standard design energy budget.

Permit applications must include heat gain documentation for the Building Plan Checker. This documentation must include a copy of the manufacturer's documentation showing the $SHGC_c$, center of glass alone and the calculation used to determine the $SHGC_{fen}$. If the proposed design uses multiple fenestration products or site-assembled fenestration products, a calculation for each different $SHGC_{fen}$ must be attached to the plans along with each glass unit manufacturer's documentation.

Mixed Fenestration Types

If mixed fenestration is included in the compliance analysis, then the compliance submittal must demonstrate which are certified fenestration products and which are non-certified fenestration or site-assembled fenestration products. The manufacturer's documentation and calculations for each product must be included in the submittal, and either the ENV-1 or PERF-1 form must be included on the building plans.

Builder and Installer Responsibilities

The builder is responsible for assuring that the glass documentation showing the SHGC used for determining compliance is provided to the installer. The builder is responsible for obtaining an NFRC Label Certificate for Site-Built Products for the building's vertical glazing if the building is 100,000 sf or more and has 10,000 sf or more of vertical glazing.

The builder is also responsible for assuring that the persons preparing compliance documentation are specifying products that the builder intends to install. The builder must assure that the glazing contractor installs the glass with the same $SHGC_c$ as used for compliance and that the building inspector is provided with manufacturers' documentation showing the $SHGC_c$ for the actual glass product installed. The builder should verify that these fenestration products are clearly shown on the building plans before fenestration products are purchased and installed.

Building Department Responsibilities - Plan Checker

The building department plan checker is responsible for assuring that the plans identify which fenestration is site-assembled and which is not. The plan-checker is responsible for verifying that the $SHGC_{fen}$ and $SHGC_c$ for non-certified fenestration products or site-assembled products is identified on the plans, that calculations have been provided showing the conversion from $SHGC_c$ to $SHGC_{fen}$, and that manufacturer documentation of the $SHGC_c$ has been provided for the fenestration to be installed. Plans should be consistent with the compliance documentation, the calculations showing the conversion from $SHGC_c$ to $SHGC_{fen}$, and Prescriptive ENV-1 Part 2 of 2 or Performance ENV-1.

Building Inspector

The building department field inspector is responsible for assuring that manufacturer's documentation has been provided for the installed fenestration. The inspector is responsible for checking the NFRC label for manufactured fenestration products, or the NFRC 100SB Label Certificate for site-built products where appropriate as described below [see "Energy Consultants, Designers, Architects: Products with SHGCs Certified to NFRC" above].

All manufactured fenestration products must have either an NFRC label or manufacturer's label with default SHGCs from Table 1-E.

All site-assembled fenestration products in buildings 100,000 sf of conditioned floor area or more and 10,000 sf of vertical fenestration area or more must have either an NFRC Label Certificate for

Site-Built Fenestration Products or a manufacturer's certificate with a default SHGC from Table 1-E.
Site-assembled vertical fenestration products in buildings less than 100,000 sf, or buildings with less than 10,000 sf of vertical glazing, may use either of the rating/labeling methods described in (b) above, or the $SHGC_{fen}$ calculation method described in this section.
Horizontal glazing that does not have a certified NFRC SHGC may use any of the above methods for determining and labeling or certifying the SHGC.
The field inspector is responsible for assuring that the certified SHGC, or $SHGC_c$ and $SHGC_{fen}$, for the installed fenestration is consistent with the plans, the Prescriptive ENV-1 Part 2 of 2 or the Performance PERF-1 and Performance ENV-1, and that manufacturer documentation is consistent with the product installed in the building. Plans shall indicate which fenestration is site-assembled or is a fenestration product without SHGCs certified to the NFRC.

Thermal Transmittance (U-Factor)

Responsibilities for Compliance

This section describes the responsibilities of energy consultants, designers, architects, builders, installers, and building departments when determining U-factor compliance.
Table I-1 provides default U-factors for skylights and site-built fenestration in buildings covered by the Nonresidential Energy Standards. The default table may be used only for the following:
Site-assembled and field-fabricated glazed wall systems in buildings covered by the Nonresidential Energy Standards that have less than 100,000 square feet of conditioned floor area or less than 10,000 square feet of vertical glazing.
Skylights in buildings covered by the Nonresidential Energy Standards.
The default Table I-1 is consistent with default U-factors published in Table 5, Chapter 29, ASHRAE Fundamentals Handbook, 1997, which is referenced in the Energy Standards.
Fenestration products fitting the two descriptions above may still use U-factors obtained through NFRC if available.

Responsibilities for Compliance

This section describes the responsibilities of energy consultants, designers, architects, builders, installers, and building departments when Table I-1 is used for determining compliance with the U-factor requirements of the Efficiency Standards.

Energy Consultants, Designers, Architects

Products with U-Factor Certified to NFRC

U-factor values can be found in the *NFRC Certified Products Directory.* Contact NFRC at 301-589-6372 for a copy of the directory or go to NFRC's website at www.nfrc.org for an online database of the directory.

Field-Fabricated Fenestration, Site-Assembled Fenestration and Fenestration Products without U-factor Certified to NFRC

To determine compliance with the efficiency standards, the Glazing Type and Frame Type shown in Table I-1 must be identified from the manufacturer's documentation for the proposed glazing.
For the Prescriptive compliance method, the U-factor must be selected from Table I-1 for this Glazing Type and Frame Type and entered into the prescriptive ENV-1 form, Part 2 of 2, and must appear on the plans.
For the Performance compliance method, the U-factor output information printed on the Performance ENV-1 form must be listed on the building plans. The PERF-1 and Performance ENV-1 forms must appear on the plans. The building plan window schedule list must indicate the

proposed total U-factors for each fenestration assembly, and these values must be equal to or less than the U-factors listed on the Performance ENV-1 computer form. The proposed design U-factors are entered into the computer program to automatically generate the energy use of the proposed design. The building complies if the total energy use of the proposed design is the same or less than the standard design energy budget.

Permit applications must include fenestration U-factor documentation for the Building Plan Checker. This documentation must include a copy of the manufacturer's documentation showing the Glazing Type information – number of panes, spacing of panes, glass type, gas fill type, coating emissivity and location – and the Frame Type – frame material type, presence of thermal breaks, and identification of structural glazing (glazing with no frame) that is used to determine the U-factor. If the proposed design uses multiple fenestration products or site-assembled fenestration products, manufacturer's documentation for each different U-factor must be attached to the plans for each glass unit. Manufacturer's documentation must be provided for each U-factor used for compliance.

Mixed Fenestration Types

If mixed fenestration is included in the compliance analysis, then the compliance submittal must demonstrate which are certified fenestration products and which are non-certified fenestration or site-assembled fenestration products. The manufacturer's documentation and calculations for each product must be included in the submittal, and either the ENV-1 or PERF-1 form must be included on the building plans.

Builder and Installer Responsibilities

The builder is responsible for assuring that the glass documentation showing the U-factor used for determining compliance is provided to the installer. The builder is responsible for assuring that the persons preparing compliance documentation are specifying products that the builder intends to install. The builder is also responsible for assuring that the installer installs glass with the same U-factor as used for compliance and assuring that the field inspector for the building department is provided with manufacturer's documentation showing the U-factor and method of determining U-factor for the actual fenestration product installed. The builder should verify that these fenestration products are clearly shown on the building plans before fenestration products are purchased and installed.

Building Department Responsibilities

Plan Checker

The building department plan checker is responsible for assuring that the plans identify which fenestration is site-assembled and which is not. The plan-checker is responsible for verifying that the U-factor for non-certified fenestration products or site-assembled products is identified on the plans, that Glazing Type and Frame Type and Table 1-I have been provided showing the method of determining the U-factor, and that manufacturer documentation of the U-factor has been provided for the fenestration to be installed. Plans should be consistent with the compliance documentation, the Glazing Type and Frame Type and Table I-1 values, and Prescriptive ENV-1 Part 2 of 2 or Performance ENV-1.

Building Inspector

The building department field inspector is responsible for assuring that manufacturer's documentation has been provided for the installed fenestration. The field inspector is responsible for assuring that the U-factor for the installed fenestration is consistent with the plans, the Prescriptive ENV-1 Part 2 of 2 or the Performance PERF-1, and Performance ENV-1, and that manufacturer documentation is consistent with the product installed in the building.

Plans shall indicate which fenestration is site-assembled or is a fenestration product without U-factor certified to NFRC.

Table B-13A –Complete Building Occupancy Assumptions When Lighting Plans are Submitted for the Entire Building or When Lighting Compliance is not Performed.

Occupancy Type	No. Occ./ 1000 sf	Sensible/ occ. (Btu)	Latent/ occ. (Btu)	Recept (Watts/sf)	Hot Water (Btuh/occ.)	Lighting (Watts/sf)	Vent. (cfm/sf)
Complete Building: Industrial Storage	5	268	403	0.43	108	0.7	0.15
Complete Building: Grocery	29	252	225	0.91	113	1.5	0.23
Complete Building: Industrial Work							
High Bay	7	375	625	1.00	120	1.2	0.15
Low Bay	7	375	625	1.00	120	1.0	0.15
Complete Building: Medical	10	250	213	1.18	110	1.2	0.15
Complete Building: Office	10	250	206	1.34	106	1.2	0.15
Complete Building: Other	10	250	200	1.00	120	0.6	0.15
Complete Building: Religious							
Worship, Auditorium, Convention	136	245	112	0.96	57	1.8	1.03
Complete Building: Restaurant	45	274	334	0.79	366	1.2	0.38
Complete Building: Retail/Wholesale	29	252	224	0.94	116	1.7	0.23
Complete Building: School	40	246	171	1.00	108	1.4	0.32
Complete Building: Theater	130	268	403	0.54	60	1.3	0.98
Complete Building: Unknown	10	250	200	1.00	120	1.2	0.15

Table B-13B –Area Category Occupancy Assumptions When Lighting Plans are Submitted for Portions or for the Entire Building or When Lighting Compliance is not Performed.

Occupancy Type	*No. Occ./ 1000 sf*	*Sensible/ occ. (Btu)*	*Latent/ occ. (Btu)*	*Recept (Watts/ sf)*	*Hot Water (Btuh/ occ.)*	*Lighting (Watts/ sf)*	*Vent (cfm/ sf)*
All Others	10	250	200	1.00	120	0.6	0.15
Auditorium	143	245	105	1.00	60	2.0	1.07
Auto Repair Workshop	10	275	475	1.00	120	1.2	1.50
Bank/Financial Institution	10	250	250	1.50	120	1.4	0.15
Bar/Cocktail Lounge/Casino	67	275	275	1.00	120	1.1	1.50
Barber & Beauty Shop	10	250	200	2.00	120	1.0	0.40
Classroom	50	245	155	1.00	120	1.6	0.38
Courtrooms	25	250	200	1.50	120	1.1	0.19
Commercial/Industrial Storage	3	275	475	0.20	120	0.6	0.15
Comm./Ind. Work-General High Bay	10	275	475	1.00	120	1.2	0.15
Comm./Ind. Work-General Low Bay	10	275	475	1.00	120	1.0	0.15
Commercial/Ind. Work-Precision	10	250	200	1.00	120	1.5	0.15
Convention/Conference/ Meeting Center	67	245	155	1.00	60	1.6	0.50
Corridor/Restroom and Support Area	10	250	250	0.20	0	0.6	0.15
Dining Area	67	275	275	0.50	385	1.1	0.50
Dry Cleaning (Coin)	10	250	250	3.00	120	1.0	0.30
Dry Cleaning (Full)	10	250	250	3.00	120	1.0	0.45
Electrical and Mechanical Room	3	250	250	0.20	0	0.7	0.15
Exercising Centers and Gymnasium	20	255	875	0.50	120	1.0	0.15
Exhibit Display Area and Museum	67	250	250	1.50	60	2.0	0.50
Grocery Sales Area	33	250	200	1.00	120	1.6	0.25
High-Rise Residential	5	245	155	0.50	n/a	0.5	0.15
Hotel Function Area	67	250	200	0.50	60	2.2	0.50
Hotel/Motel Guest Room	5	245	155	0.50	2800	0.5	0.15
Kitchen and Food Preparation	5	275	475	1.50	385	1.7	0.15
Laundry	10	250	250	3.00	385	0.9	0.15
Library - Reading Areas	20	250	200	1.50	120	1.2	0.15
Library - Stacks	10	250	200	1.50	120	1.5	0.15
Lobby (Hotel)	10	250	250	0.50	120	2.2	0.15
Lobby (Main Entry and Assembly)	143	250	250	0.50	60	1.5	1.07
Lobby (Office Reception and Waiting)	10	250	250	0.50	120	1.1	0.15
Locker and Dressing Room	20	255	475	0.50	385	0.9	0.15
Mall/Arcade/Atrium	33	250	250	0.50	120	1.2	0.25
Medical/Clinical Care	10	250	200	1.50	160	1.4	0.15
Office	10	250	200	1.50	120	1.3	0.15
Police Station and Fire Station	10	250	200	1.50	120	0.9	0.15
Religious Worship	143	245	105	0.50	60	2.1	1.07

Occupancy Type	*No. Occ./ 1000 sf*	*Sensible/ occ. (Btu)*	*Latent/ occ. (Btu)*	*Recept (Watts/ sf)*	*Hot Water (Btuh/ occ.)*	*Lighting (Watts/ sf)*	*Vent (cfm/ sf)*
Retail Sales and Wholesale Showroom	33	250	200	1.00	120	2.0	0.25
Smoking Lounge	67	275	275	0.50	120	1.1	1.50
Theater (Motion Picture)	143	245	105	0.50	60	0.9	1.07
Theater (Performance)	143	245	105	0.50	60	1.4	1.07
Unknown Nonresidential	10	250	200	1.00	120	0.8	0.15

Table B-14 – Assembly U-Factors for Unlabeled Glazed Wall Systems (Site-Built Windows) and Unlabeled Skylights

Product Type		Vertical Installation				Sloped Installation						
		Unlabeled Glazed Wall Systems (Site Built Windows) (include site assembled fixed windows only, does not include operable windows)				**Unlabeled Skylight with Curb** (includes glass/plastic, flat/domed, fixed/operable)				**Unlabeled Skylight without Curb** (includes glass/plastic, flat/domed, fixed/operable)		
Frame Type		Aluminum without Thermal Break	Aluminum with Thermal Break	Wood/ Vinyl	Structural Glazing	Aluminum without Thermal Break	Aluminum with Thermal Break	Reinforced Vinyl/ Aluminum Clad Wood	Wood/ Vinyl	Aluminum without Thermal Break	Aluminum with Thermal Break	Structural Glazing
ID	**Glazing Type**											
	Single Glazing											
1	1/8" glass	1.22	1.11	0.98	1.11	1.98	1.89	1.75	1.47	1.36	1.25	1.25
2	1/4" acrylic/polycarb	1.08	0.96	0.84	0.96	1.82	1.73	1.60	1.31	1.21	1.10	1.10
3	1/8" acrylic/polycarb	1.15	1.04	0.91	1.04	1.90	1.81	1.68	1.39	1.29	1.18	1.18
	Double Glazing											
4	1/4" airspace	0.79	0.68	0.56	0.63	1.31	1.11	1.05	0.84	0.82	0.70	0.66
5	1/2" airspace	0.73	0.62	0.50	0.57	1.30	1.10	1.04	0.84	0.81	0.69	0.65
6	1/4" argon space	0.75	0.64	0.52	0.60	1.27	1.07	1.00	0.80	0.77	0.66	0.62
7	1/2" argon space	0.70	0.59	0.48	0.55	1.27	1.07	1.00	0.80	0.77	0.66	0.62
	Double Glazing, *e*=0.60 on surface 2 or 3											
8	1/4" airspace	0.76	0.65	0.53	0.61	1.27	1.08	1.01	0.81	0.78	0.67	0.63
9	1/2" airspace	0.69	0.58	0.47	0.54	1.27	1.07	1.00	0.80	0.77	0.66	0.62
10	1/4" argon space	0.72	0.61	0.49	0.56	1.23	1.03	0.97	0.76	0.74	0.63	0.58
11	1/2" argon space	0.67	0.56	0.44	0.51	1.23	1.03	0.97	0.76	0.74	0.63	0.58
	Double Glazing, *e*=0.40 on surface 2 or 3											
12	1/4" airspace	0.74	0.63	0.51	0.58	1.25	1.05	0.99	0.78	0.76	0.64	0.60
13	1/2" airspace	0.66	0.55	0.44	0.51	1.24	1.04	0.98	0.77	0.75	0.64	0.59
14	1/4" argon space	0.69	0.57	0.46	0.53	1.18	0.99	0.92	0.72	0.70	0.58	0.54
15	1/2" argon space	0.63	0.51	0.40	0.47	1.20	1.00	0.94	0.74	0.71	0.60	0.56
	Double Glazing, *e*=0.20 on surface 2 or 3											
16	1/4" airspace	0.70	0.59	0.48	0.55	1.20	1.00	0.94	0.74	0.71	0.60	0.56
17	1/2" airspace	0.62	0.51	0.39	0.46	1.20	1.00	0.94	0.74	0.71	0.60	0.56
18	1/4" argon space	0.64	0.53	0.42	0.49	1.14	0.94	0.88	0.68	0.65	0.54	0.50
19	1/2" argon space	0.57	0.46	0.35	0.42	1.15	0.95	0.89	0.68	0.66	0.55	0.51
	Double Glazing, *e*=0.10 on surface 2 or 3											
20	1/4" airspace	0.68	0.57	0.45	0.52	1.18	0.99	0.92	0.72	0.70	0.58	0.54
21	1/2" airspace	0.59	0.48	0.37	0.44	1.18	0.99	0.92	0.72	0.70	0.58	0.54
22	1/4" argon space	0.62	0.51	0.39	0.46	1.11	0.91	0.85	0.65	0.63	0.52	0.47
23	1/2" argon space	0.55	0.44	0.33	0.39	1.13	0.93	0.87	0.67	0.65	0.53	0.49
	Double Glazing, *e*=0.05 on surface 2 or 3											
24	1/4" airspace	0.67	0.56	0.44	0.51	1.17	0.97	0.91	0.70	0.68	0.57	0.52
25	1/2" airspace	0.57	0.46	0.35	0.42	1.17	0.98	0.91	0.71	0.69	0.58	0.53
26	1/4" argon space	0.60	0.49	0.38	0.44	1.09	0.89	0.83	0.63	0.61	0.50	0.45
27	1/2" argon space	0.53	0.42	0.31	0.38	1.11	0.91	0.85	0.65	0.63	0.52	0.47
	Triple Glazing											
28	1/4" airspaces	0.63	0.52	0.41	0.47	1.12	0.89	0.84	0.64	0.64	0.53	0.48
29	1/2" airspaces	0.57	0.46	0.35	0.41	1.10	0.87	0.81	0.61	0.62	0.51	0.45
30	1/4" argon spaces	0.60	0.49	0.38	0.43	1.09	0.86	0.80	0.60	0.61	0.50	0.44
31	1/2" argon spaces	0.55	0.45	0.34	0.39	1.07	0.84	0.79	0.59	0.59	0.48	0.42
	Triple Glazing, *e*=0.20 on surface 2,3,4, or 5											
32	1/4" airspaces	0.59	0.48	0.37	0.42	1.08	0.85	0.79	0.59	0.60	0.49	0.43
33	1/2" airspaces	0.52	0.41	0.30	0.35	1.05	0.82	0.77	0.57	0.57	0.46	0.41
34	1/4" argon spaces	0.54	0.44	0.33	0.38	1.02	0.79	0.74	0.54	0.55	0.44	0.38
35	1/2" argon spaces	0.49	0.38	0.28	0.33	1.01	0.78	0.73	0.53	0.54	0.43	0.37
	Triple Glazing, *e*=0.20 on surfaces 2 or 3 and 4 or 5											
36	1/4" airspaces	0.55	0.45	0.34	0.39	1.03	0.80	0.75	0.55	0.56	0.45	0.39
37	1/2" airspaces	0.48	0.37	0.26	0.31	1.01	0.78	0.73	0.53	0.54	0.43	0.37

Product Type		Vertical Installation				Sloped Installation						
		Unlabeled Glazed Wall Systems (Site Built Windows) (include site assembled fixed windows only, does not include operable windows)				**Unlabeled Skylight with Curb** (includes glass/plastic, flat/domed, fixed/operable)				**Unlabeled Skylight without Curb** (includes glass/plastic, flat/domed, fixed/operable)		
Frame Type		Aluminum without Thermal Break	Aluminum with Thermal Break	Wood/ Vinyl	Structural Glazing	Aluminum without Thermal Break	Aluminum with Thermal Break	Reinforced Vinyl/ Aluminum Clad Wood	Wood/ Vinyl	Aluminum without Thermal Break	Aluminum with Thermal Break	Structural Glazing
38	1/4" argon spaces	0.50	0.39	0.29	0.34	0.99	0.75	0.70	0.50	0.51	0.40	0.35
39	1/2" argon spaces	0.45	0.34	0.24	0.29	0.97	0.74	0.69	0.49	0.50	0.39	0.33
	Triple Glazing, *e*=0.10 on surfaces 2 or 3 and 4 or 5											
40	1/4" airspaces	0.54	0.43	0.32	0.37	1.01	0.78	0.73	0.53	0.54	0.43	0.37
41	1/2" airspaces	0.46	0.35	0.25	0.29	0.99	0.76	0.71	0.51	0.52	0.41	0.36
42	1/4" argon spaces	0.48	0.38	0.27	0.32	0.96	0.73	0.68	0.48	0.49	0.38	0.32
43	1/2" argon spaces	0.42	0.32	0.21	0.26	0.95	0.72	0.67	0.47	0.48	0.37	0.31
	Quadruple Glazing, *e*=0.10 on surfaces 2 or 3 and 4 or 5											
44	1/4" airspaces	0.49	0.38	0.28	0.33	0.97	0.74	0.69	0.49	0.50	0.39	0.33
45	1/2" airspaces	0.43	0.32	0.22	0.27	0.94	0.71	0.66	0.46	0.47	0.36	0.30
46	1/4" argon spaces	0.45	0.34	0.24	0.29	0.93	0.70	0.65	0.45	0.46	0.35	0.30
47	1/2" argon spaces	0.41	0.30	0.20	0.24	0.91	0.68	0.63	0.43	0.44	0.33	0.28
48	1/4" krypton spaces	0.41	0.30	0.20	0.24	0.88	0.65	0.60	0.40	0.42	0.31	0.25